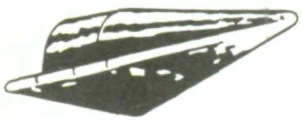

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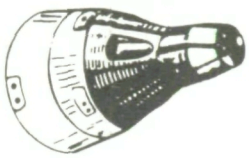
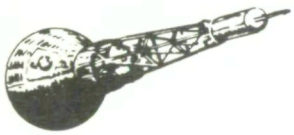




MDC E0377

Phase B System Study
FINAL REPORT

DETAIL
MASS PROPERTIES REPORT

Part III (B)

BOOSTER DETAILS

HIGH VALUE

SPACE SHUTTLE

LOW COST

MCDONNELL DOUGLAS CORPORATION

MARTIN MARIETTA DENVER DIVISION

TRW SYSTEMS GROUP

PAN AM

(NASA-CR-143903) SPACE SHUTTLE PHASE B SYSTEM STUDY. PART 3(B): BOOSTER DETAILS. DETAIL MASS PROPERTIES REPORT Final Report (McDonnell-Douglas Corp.) 223 p

N75-76043

Unclas

00/98 17887

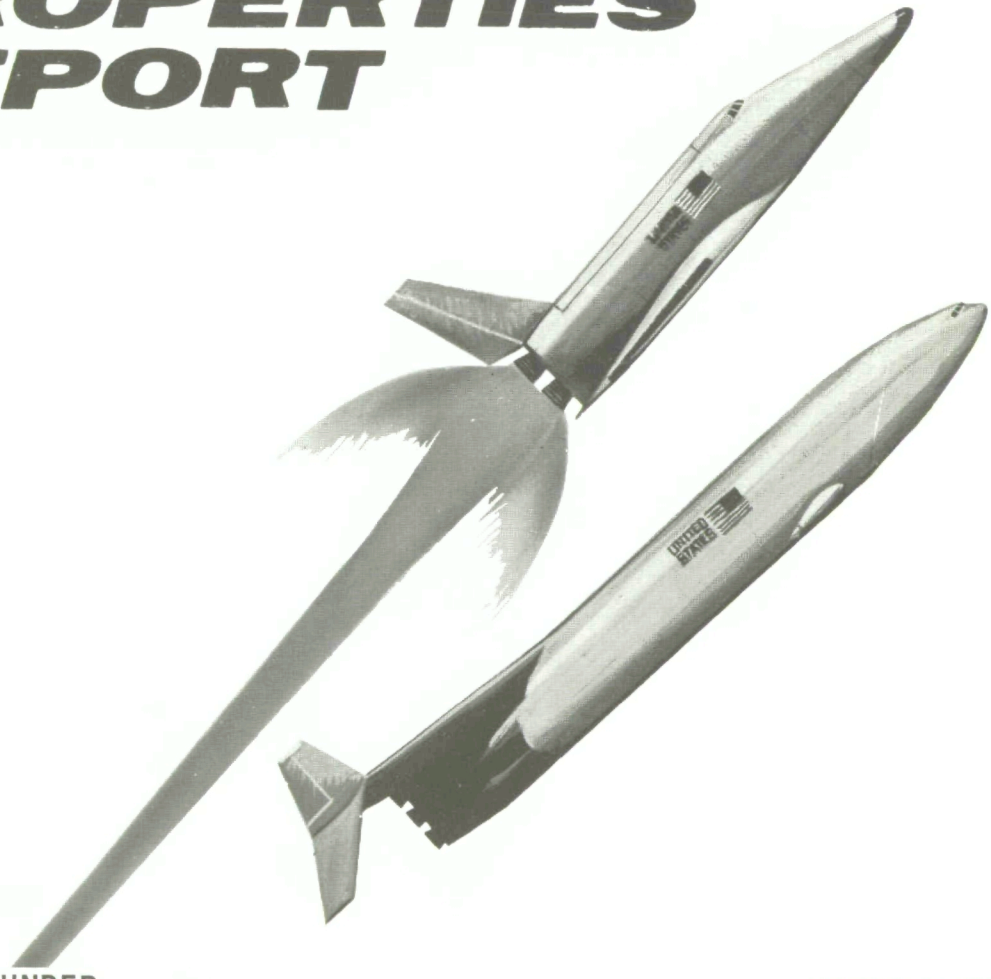
REPORT MDC E0377
30 JUNE 1971

Space Shuttle System

PHASE B STUDY FINAL REPORT

Part III (B)
Booster Details

DETAIL MASS PROPERTIES REPORT



SUBMITTED UNDER

NASA CONTRACT NO. NAS 8-26016

DRD MA016M- DRL LINE ITEM 23

MCDONNELL DOUGLAS CORPORATION
MARTIN MARIETTA DENVER DIVISION
PAN AM
TRW SYSTEMS GROUP

VOLUME III

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4. INDUCED ENVIRONMENT PROTECTION

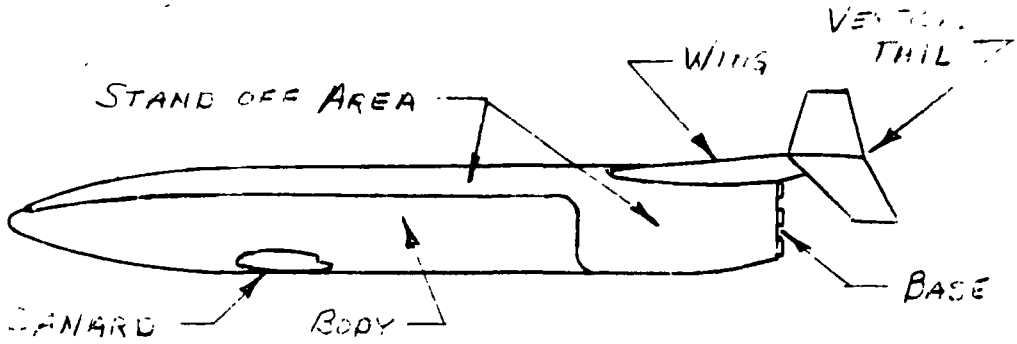
84807

	SUPT.ITEMS	RAILS	PANELS	WEIGHT (LB)	PAGE NO.
WING				[16450]	2.4-23
STRUCTURE	3073	522	3739	7333	
HCF				5203	
COATING				2459	
BOND				1455	
FIN				[6596]	2.4-24
STRUCTURE	1356	220	1368	2944	
HCF				2035	
COATING				1009	
BOND				608	
CANARD				[4524]	2.4-26
STRUCTURE	876	148	896	1920	
HCF				1489	
COATING				701	
BOND				414	
BODY				[47969]	2.4-27
STRUCTURE	9896	2486	8819	21201	
HCF				14449	
COATING				7626	
BOND				4693	
BASE HEAT PROTECTION				[5678]	2.4-28
BASE HEAT PANELS STA 3862				(3138)	
NOZZLE MOUNTED DISKS				1350	
INTERIOR PANELS				585	
SIDE PANELS				496	
CORNER PANELS				92	
BRUSH SEAL ASSY				615	

	WEIGHT (LB)	PAGE NO.
SUPPORT STRUCTURE	(625)	
MAIN STRUTS	255	
SECONDARY STRUTS	63	
CHANNELS (PANELS)	126	
MAIN STRUT SUPT BRACKET	37	
SEC. STRUT ATTACH FITTINGS	12	
PERIMETER SUPT ANGLE	107	
PANEL EDGE SUPPORT	25	
BOAT TAIL PANELS	(1635)	
ATTACHING PARTS	(280)	
STAND-OFFS	[3327]	2.4-40
INSTRUMENTATION	[263]	2.4-45

NOTE: LEADING EDGES AND NOSE CAP WEIGHT ARE CARRIED IN WING, TAIL AND BODY GROUPS

THERMAL PROTECTION SYSTEM (TPS)



4. INDUCED ENVIRONMENT PROTECTION

THERMAL PROTECTION	WING	CANARD	VER. TAIL	BODY	(84807)
LEADING EDGE/NOSE CAP*	( )	( )	( )	( )	
METALLIC HOT STRUCTURE					
CARRIED IN WING, TAIL					
AND BODY GROUPS					
SURFACE PROTECTION*	(16450)	(4524)	(6596)	(47969)	75539
STRUCTURE	7333	1920	2944	21201	
HCF	5203	1489	2035	14449	
COATING	2459	701	1009	7626	
BOND	1455	414	608	4693	
BASE HEAT PROTECTION*				( )	5678
STAND OFFS					3327
INSTRUMENTATION					263
SOUND PROTECTION					( )
METEORITE/RADIATION PROTECTION					( )

*BREAK OUT BY TYPE OF MATERIAL

T.P.S.
Detailed Weight Substantiation

The T.P.S. is divided into six main categories for weights calculation, each for its particular function. These are support items, rails, subpanels, HCF, coating and bond.

Support items consist of the panel edge treatment, rail attachments and joint insulation; all are a function of panel size. Panels of 26 x 30 inch are generally used on all lower surfaces and all fin surfaces. Panels of 26 x 60 inch are generally used on all upper surfaces. The adhesive and skrim cloth, which is part of the subpanel are constant for all size panels.

The rails, for the standard standoff height, are of constant weight throughout the vehicle except for the shoulder area of the body where the rail height changes, as well as pressures changes along the booster/orbiter interference areas.

Hexagonal sandwiched panels are used for the structural support of the T.P.S. The faces are constructed of graphite epoxy and the core is made of glass epoxy material. The subpanel weight are a function of air loading (either positive or negative) and on the location of the panel.

The HCF (Hardened Compacted Fibers) weight (or thickness) is a function of the heating requirements during ascent or entry and are reflected on the charts in the following TPS substantiation section.

The coating on the HCF is a function of T.P.S. area (for exposed face) and HCF thickness (for edge coating of 6 x 6 inch tile).

The bond weight is a function of exposed T.P.S. area only and is used to hold the HCF to the subpanels.

SUMMARY OF TPS AREA & UNIT WEIGHT

	FT^2	PSF
WING	(8391)	
- WING LESS L.E.	8081	2.036
- LEADING EDGE (COLUMBIUM)*	310	
FIN	(3598)	
- DORSAL LESS L.E.	1903	1.955
- VENTRAL LESS L.E.	1672	
- DORSAL LEADING EDGE (HASTELLOY)*	96	
- VENTRAL - LEADING EDGE (COLUMBIUM)*	127	
CANARD	(2397)	
- CANARD LESS L.E.	2301	1.967
- LEADING EDGE (HASTELLOY)*	96	
BODY	(26121)	
- BODY LESS NOSE	26071	1.840
- NOSE (HASTELLOY)*	50	
TOTAL	40507	1.939
TOTAL LESS LEADING EDGE	39828	1.897
TOTAL LEADING EDGE*	679	4.423

* FOR REF. ONLY WEIGHT CARRIED IN WING, TAIL AND BODY GROUPS

UNIT WEIGHTS DO NOT INCLUDE. BASE, STANDOFFS OR INSTRUMENTION

SUMMARY OF TPS STRUCTURE UNIT WEIGHTS (PSF)

SUPPORT ITEMS

	SUPPORT UNIT WEIGHT	
PANEL SIZE (IN)	36 X 30	26X60
EDGING	.0199	.0153
RAIL ATTACHMENTS	.0765	.0765
JOINT INSULATION	.1370	.1010
ADHESIVE (H.C.)	.150	.150
SKRIM CLOTH (HC.)	.017	.017
TOTAL	.4004	.3598

RAILS

	RAIL UNIT WEIGHT VS LOADING			
LOADING (PSI)	3.4	4.0	5.75	11.0
STANDARD STRINGOFF	–	.0645*	–	–
SHOULDER AREA	.119*	–	.156	.234

SUBPANEL (HC)

	SUBPANEL UNIT WEIGHT FOR POSITIVE LOADS					
LOADING (PSI)	1.4	2.0	3.0	4.0	8.0	11.0
WING, FIN, CANARD	.312	.360	.408	.456	–	–
BODY	.312	.327	.376	.407	.524	.627

	SUBPANEL UNIT WEIGHT FOR NEGATIVE LOADS					
LOADING (PSI)	-0.7	-1.5	-2.5	-3.0	-4.0	-5.0
WING, FINS	.312	.405	.533	.580	.722	.865
CANARDS	.312	–	.374	–	.517	.596

*MINIMUM GAGE EXTRUSION

ALL LOADS ARE ULTIMATE LOADS

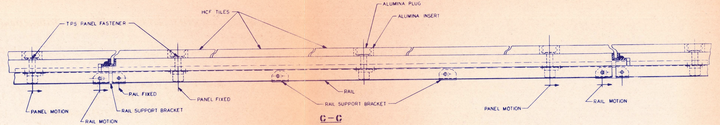
SUPPORT ITEMS WEIGHT BREAKDOWN

		WEIGHT LB	UNIT WT PSF
RAIL ATTACHMENTS* 26"x30"		(.410)	[.0765]
1/4 TURN FASTENERS	(2)	.1422	
FACE MAT'L GR/EP		.0284	
TITANIUM SHIMS	(6)	.0154	
INSERTS GL/EP	(3)	.0295	
RAIL SUPPORT AL	(3)	.1582	
PINS ST	(3)	.0360	
SKRIM CLOTH* - HONEYCOMB PANEL			[.0170]
ADHESIVE* - HONEYCOMB PANEL			[.150]
EDGING**			
26"x30" PANEL SIZE		(.108)	[.0199]
MEMBER - LONGITUDINAL		.058	
- LATERAL		.050	
26"x60" PANEL SIZE		(.166)	[.0153]
MEMBER - LONGITUDINAL		.116	
- LATERAL		.050	
JOINT INSULATION**			
26"x30" PANEL		(.7423)	[.1370]
Ti. SEAL RETAINER	- LONG	.0575	
	- LAT	.0498	
SILASTIC 651 SEAL	- LONG	.0322	
	- LAT	.0278	
ZIRCONIA FOAM	- LONG	.1560	
	- LAT	.1505	
CARBON PHENOLIC	- LONG	.1050	
	- LAT	.1138	
RIGID PHENOLIC FOAM	- LONG	.0282	
	- LAT	.0215	

SUPPORT ITEMS WEIGHT BREAKDOWN (CON'T)

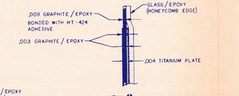
		WEIGHT LB	UNIT WT PSF
JOINT INSULATION **			
26" X 60" PANEL		(1.093)	[.1010]
TI. SEAL RETAINER	-LONG	.1150	
	-LAT	.0498	
SILASTIC 651 SEAL	-LONG	.0644	
	-LAT	.0278	
ZIRCONIA FOAM	-LONG	.3120	
	-LAT	.1505	
CARBON PHENOLIC	-LONG	.2100	
	-LAT	.1138	
RIGID PHENOLIC FOAM	-LONG	.0282	
	-LAT	.0215	

* NOT A FUNCTION OF PANEL SIZE
** FUNCTION OF PANEL SIZE
GR/EP = GRAPHITE EPOXY
GL/EP = GLASS EPOXY

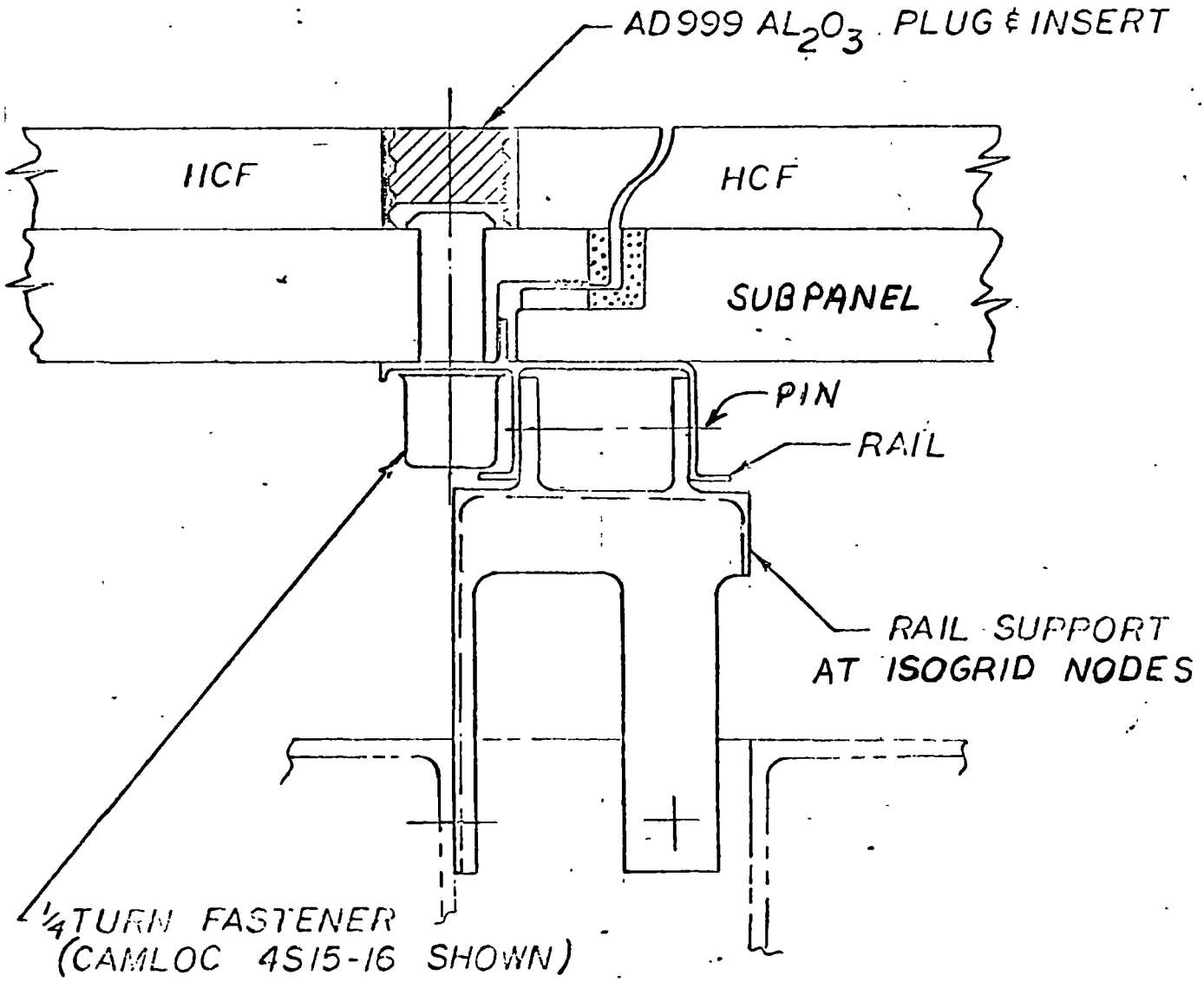


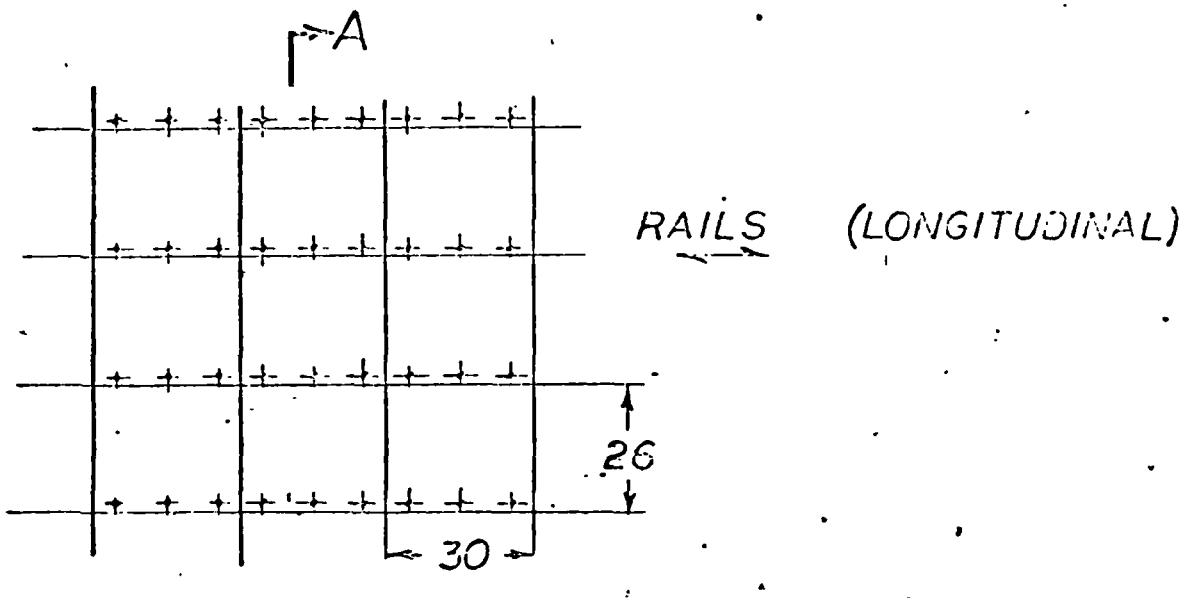
C–C
RAIL SUPPORT BRACKETS ATTACHED TO STRUCTURE AS REQUIRED

TYPICAL SECTION OF HCF THICKNESS TRANSITION

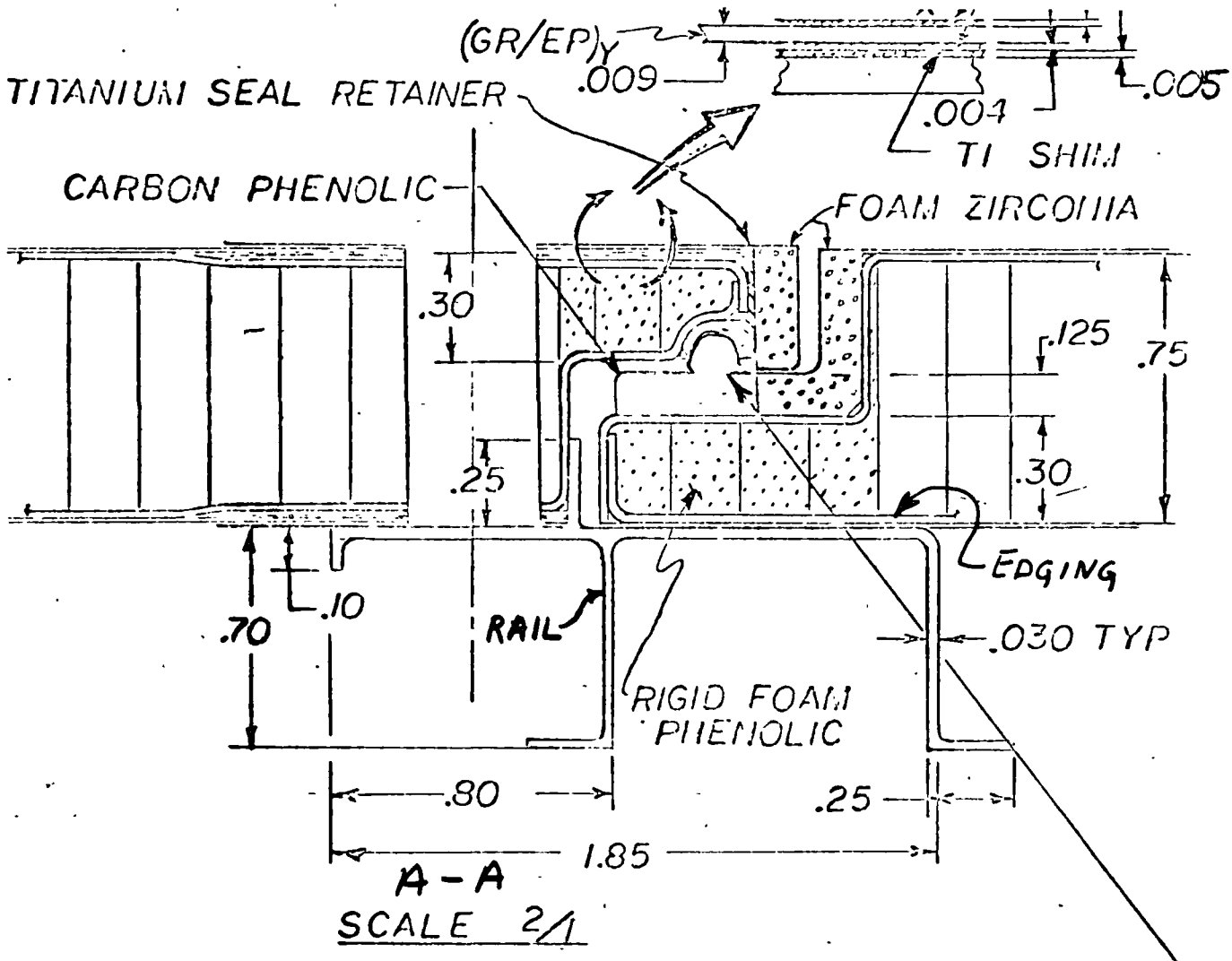


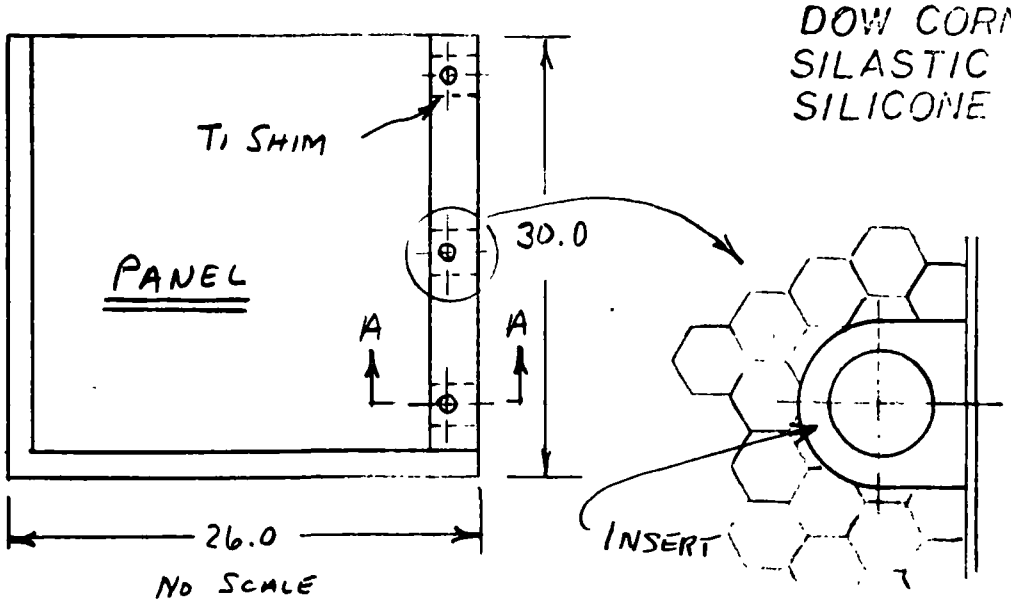
VIEW D
SCALE 3/1





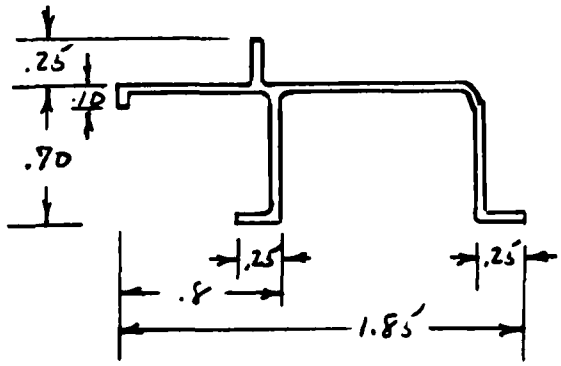
LOWER BODY PANELS


(GR/EP)Y
.009
.004
.005
TITANIUM SEAL RETAINER
TI SHIM
CARBON PHENOLIC
FOAM ZIRCONIA
.30
.125
.75
.25
.30
EDGING
.70
.10
RAIL
.030 TYP
RIGID FOAM PHENOLIC
.80
.25
1.85
A-A
SCALE 2/1
DOW CORNING SILASTIC 651 SILICONE SEAL


TI SHIM
PANEL
30.0
A
A
26.0
INSERT
NO SCALE

RAILS

BODY – NON SHOULDER REGION



MATL - 7075-T73511 EXT.

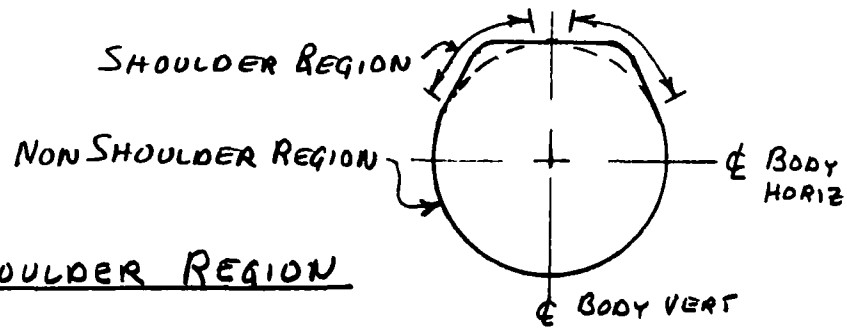
$A = .1155\ IN^2$

$\rho = .101\ LB/IN^3$

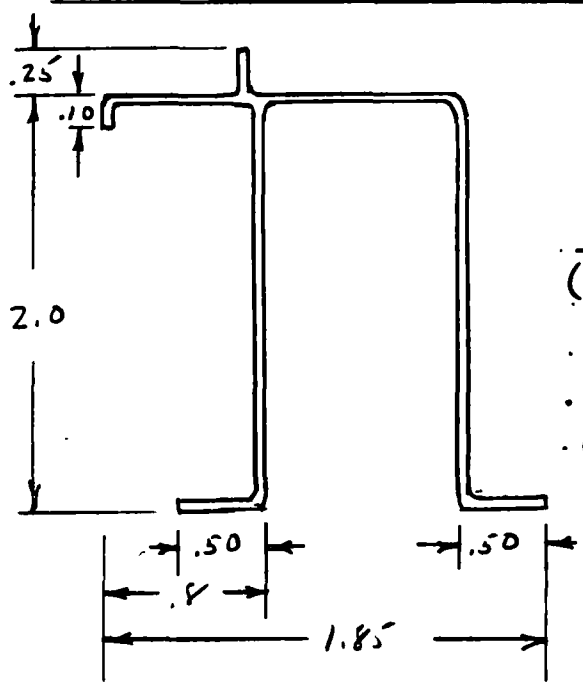
$WT = .0645\ LB/FT^2$

PRESSURE = 4.00 PSI ULT

$t = .030$



BODY – SHOULDER REGION



MATL - 7075-T73511 EXT.

$\rho = .101\ LB/IN^3$

t (IN)	A (IN^2)	WT LB/FT^2	PRESS (PSI-ULT)
.030	.209	.117	3.4
.040	.279	.156	5.75
.060	.418	.234	11.0

NOTE: MINIMUM GAGE FOR EXTRUSIONS – .030

SUB PANELS

AIR PRESS. (PSI-ULT)	FACE t (IN)	CORE t (IN)	CELL SIZE (HEX-IN.)	CELL DENSITY (PCF)	UNIT WEIGHT (PSF)
AEROSURFACES					
1.4	.011	.75	3/8	2.2	.312
2.0	.015	.75	3/8	2.2	.360
3.0	.012	.75	1/4	3.5	.408
4.0	.015	.75	1/4	3.5	.456
BODY					
1.4	.011	.75	3/8	2.2	.312
2.0	.012	.75	3/8	2.2	.317
3.0	.010	.75	1/4	3.5	.376
4.0	.012	.75	1/4	3.5	.408
8.0	.017	.75	3/16	4.0	.524
11.0	.020	.75	3/16	4.0	.627
UPPER WING AND FINS					
-.7	.011	.75	3/8	2.2	.312
-1.5	.014	1.00	3/8	2.2	.405
-2.5	.022	1.00	3/8	2.2	.533
-3.0	.025	1.00	3/8	2.2	.580
-4.0	.034	1.00	3/8	2.2	.722
-5.0	.043	1.00	3/8	2.2	.865
UPPER CANARD					
-.7	.011	.75	3/8	2.2	.312
-2.5	.012	1.00	3/8	2.2	.374
-4.0	.020	1.00	3/8	2.2	.517
-5.0	.028	1.00	3/8	2.2	.596

NOTE:

FACES ARE GRAHITE EPOXY $\rho = .058$ LB/IN^3

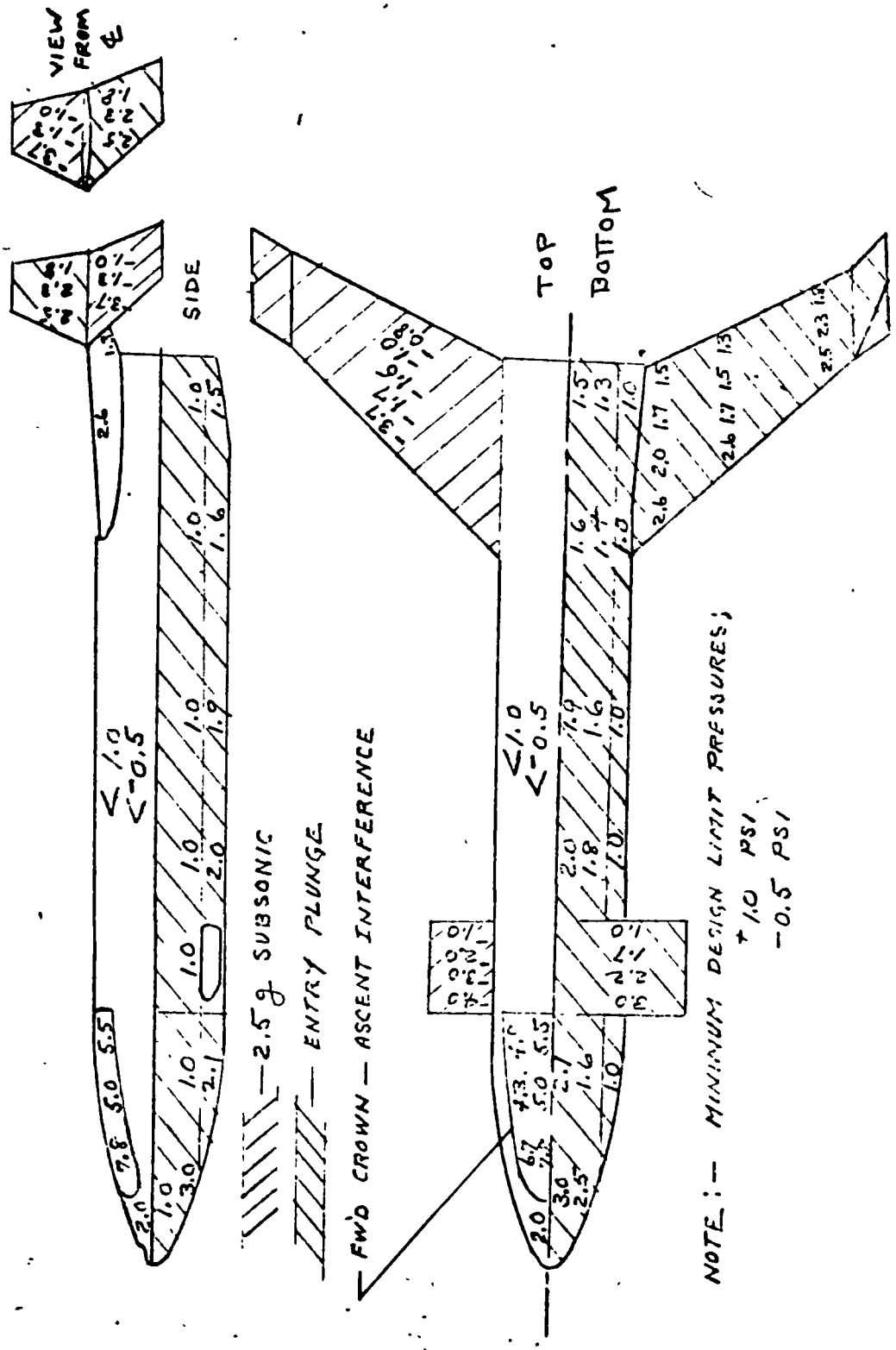
CORE IS GLASS EPOXY $\rho = .060$ LB/IN^3

SUB PANEL WEIGHT CONSISTS OF FACES AND CORE ONLY
SKRIM CLOTH AND ADHESIVE IS WITH SUPPORT ITEMS

SUBPANEL AREAS
IN PERCENT OF TOTAL TPS AREA*

POSITIVE AIR LOAD (PSI)		1.4	2.0	3.0	4.0	8.0	11.0
WING - LOWER	10.15	4.85	1.25	1.60	2.45		
FIN - UP. - OUTBD	2.125	1.025	.275	.325	.50		
- LW. - INBD	2.125	1.025	.275	.325	.50		
CANARD - LOWER	2.90	1.65	.60	.35	.40		
BODY - UPPER	28.70	28.70	—	—	—		
- UP - FWD	4.30	—	—	—	—	2.70	1.60
- LOWER	32.40	13.00	12.40	6.00	1.00		
NEGATIVE AIR LOAD (PSI)		-0.7	-1.5	-2.5	-3.0	-4.0	-5.0
WING - UPPER	10.15	—	2.60	5.25	.80	.60	.90
FIN - UP. - INBD	2.125	1.025	.25	.57	.10	.08	.10
- LW - OUTBD	2.125	1.025	.25	.57	.10	.08	.10
CANARD - UPPER	2.90	1.45	—	.40	—	.45	.60
TOTAL	100.00						

* 39829 FT^2 LESS LEADING EDGE AREA



BOOSTER DESIGN LIMIT PRESSURES (PSI) FOR TPS SIZING
(CONFIGURATION 20A - POLAR ORBIT MISSION)

NOTE:- MINIMUM DESIGN LIMIT PRESSURES;
+1.0 PSI
-0.5 PSI

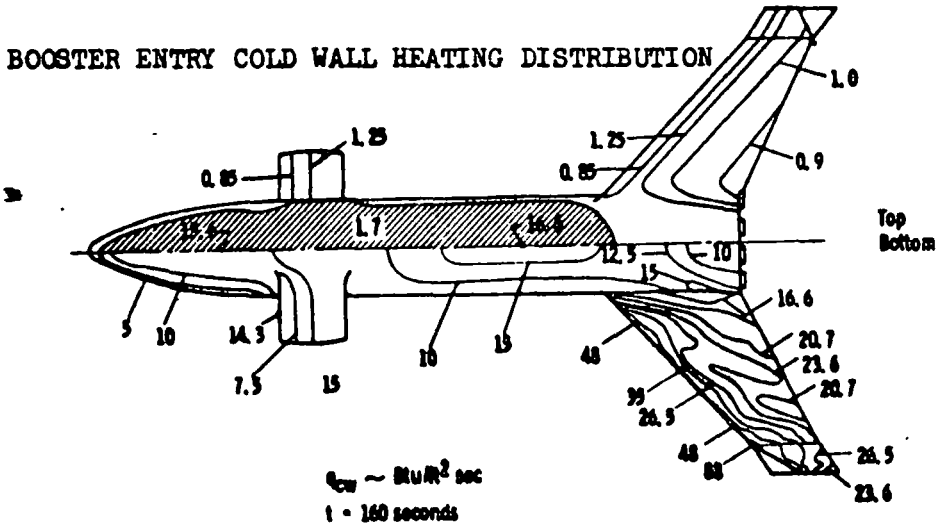
HCF THICKNESSES IN PERCENT OF AREA

		AREA (FT^2)			
		8081	3375	2301	26071
t	UNIT WT	WING	FIN	CANARD	BODY
.25	.313	23.2	–	–	14.7
.30	.375	6.4	11.3	18.4	13.9
.35	.438	7.1	14.4	4.2	9.2
.40	.500	5.7	37.5	5.9	10.9
.45	.563	4.0	9.9	6.4	13.0
.50	.625	3.2	2.5	4.1	9.5
.55	.688	3.7	–	5.5	9.3
.60	.750	5.9	–	32.0	8.0
.65	.812	8.8	2.5	23.5	4.7
.70	.875	9.6	5.0	–	2.0
.75	.938	8.0	6.4	–	1.0
.80	1.000	12.6	5.0	–	1.0
.85	1.063	1.8	2.0	–	2.8
.90	1.125	–	–	–	–
.95	1.188	–	1.0	–	–
1.00	1.250	–	2.5	–	–
		100.0	100.0	100.0	100.0
t_{AVE}		.515	.482	.518	.443

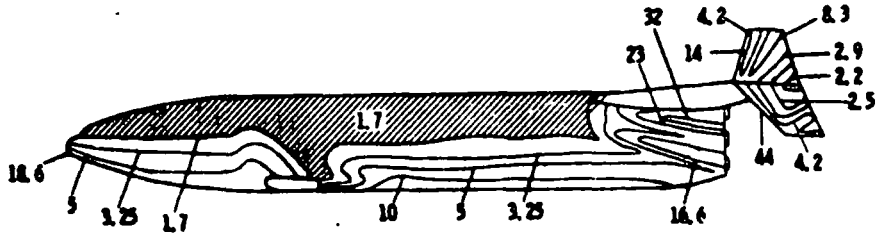
NOTE: AREAS DO NOT INCLUDE LEADING EDGES
HCF DENSITY = 15.0 LB/FT^3

DEN 066037 (3-67)

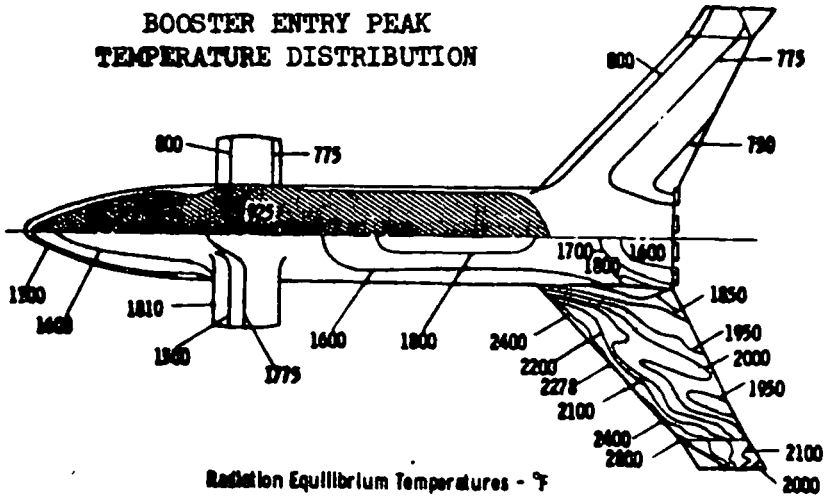
BOOSTER ENTRY COLD WALL HEATING DISTRIBUTION



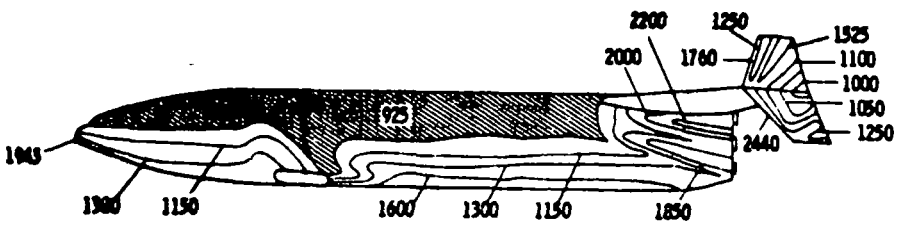
q_{cw} ~ Btu/ft^2 sec
t = 160 seconds



BOOSTER ENTRY PEAK
TEMPERATURE DISTRIBUTION

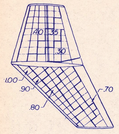


Radiation Equilibrium Temperatures - °F
ε = 0.8



BODY TPS GAP SUMMARY

BODY LOCATION	TRANSVERSE ASSEMBLY	TRANSVERSE ASCENT MIN/MAX	TRANSVERSE ENTRY MIN/MAX	LONGITUDINAL ASSEMBLY	LONGITUDINAL ASCENT MIN/MAX	LONGITUDINAL ENTRY MIN/MAX
LO_2 TANK STA 1883						
POINT 1 (L-30)	.119±.030	.004/.064	0/.060	.137±.030	.061/.121	0/.060
POINT 2 (L-30)	.114±.030	.017/.077	0/.060	.137±.030	.060/.120	0/.060
POINT 3 (L-60)	.178 .030	.022/.082	0/.060	"	"	"
POINT 4 (L-60)	.186±.030	.012/.072	0/.060	.137±.030	.059/.119	0/.060
INTERTANK STA 2003						
POINT 1 (L-30)	.181±.030	0/.060	.124/.184	.036±.030	0/.060	0/.060
POINT 2 (L-30)	.150±.030	0/.060	.097/.157	.036±.030	0/.060	0/.060
POINT 3 (L-60)	.262±.030	0/.060	.201/.261	"	"	"
POINT 4 (L-60)	.156±.030	0/.060	.069/.129	.036±.030	0/.060	0/.060
LH_2 TANK STA 2163						
POINT 1 (L-30)	.176±.030	0/.060	.116/.176	.051±.030	0/.060	.024/.084
POINT 2 (L-30)	.136±.030	0/.060	.079/.139	.051±.030	0/.060	.040/.100
POINT 3 (L-60)	.234±.030	0/.060	.164/.224	"	"	"
POINT 4 (L-60)	.209±.030	0/.060	.131/.191	.051±.030	0/.060	0/.060
LH_2 TANK STA 3036						
POINT 1 (L-30)	.138±.030	0/.060	.066/.126	.051±.030	0/.060	.017/.077
POINT 2 (L-30)	.135±.030	0/.060	.077/.137	.051±.030	0/.060	.030/.090
POINT 3 L-60	.232±.030	0/.060	.154/.214	"	"	"
POINT 4 L-60	.355 .030	0/.060	.294/.344	.051±.030	0/.060	.033/.093
(GAP) →						



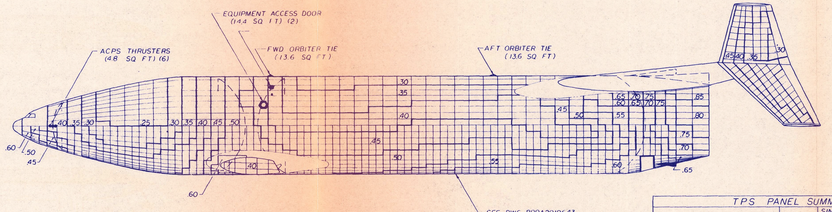
WING TPS GAP SUMMARY (CHORDWISE GAPS)

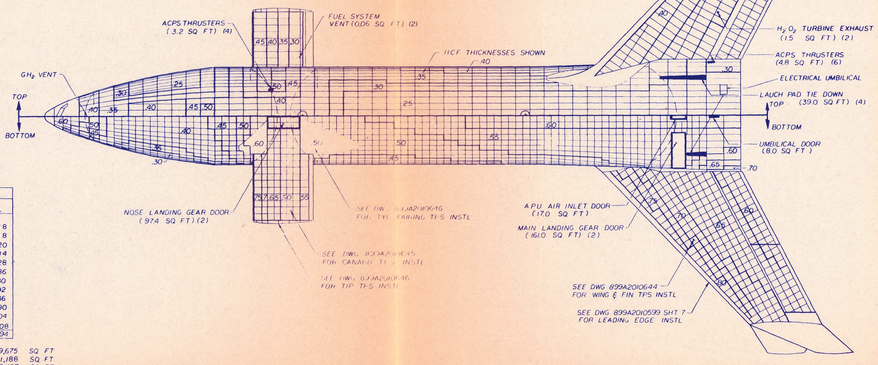
LOCATION	UPPER SURFACE ASSEMBLY	UPPER SURFACE MAX q_a HW MIN/MAX	UPPER SURFACE MAX q_a TW MIN/MAX	UPPER SURFACE ENTRY MIN/MAX	LOWER SURFACE ASSEMBLY	LOWER SURFACE MAX q_a HW MIN/MAX	LOWER SURFACE MAX q_a TW MIN/MAX	LOWER SURFACE ENTRY MIN/MAX
WING ROOT	.113±.030	0/.060	.146/.206	0/.060	.221±.030	.190/.250	0/.060	.134/.194
RIB "2	.135±.030	.006/.066	.164/.224	0/.060	.221±.030	.207/.267	0/.060	.189/.249
RIB "4	.135±.030	.038/.098	.138/.198	0/.060	.101±.030	.181/.241	0/.060	.167/.227
OUTBD ELEVON ACTUATOR	.126±.030	.023/.083	.115/.175	0/.060	.084±.030	.148/.208	0/.060	.147/.207
WING TIP	.139±.030	.037/.097	.120/.180	0/.060	.072±.030	.152/.212	0/.060	.156/.216
(GAP) →								

DESIGN REQUIREMENTS

A. FUNCTION
1. SUSTAIN TEMPERATURES
   a. PREVENT ENTRY OF HOT BOUNDARY LAYER GASES.
   b. PREVENT RADIATION AND CONVECTION THROUGH THE GAPS.
2. BE IMPERVIOUS TO MOISTURE.
3. RESIST HAIL, SALT AIR, FUNGI, DUST.
4. SUSTAIN AIRLOADS AND ACOUSTIC, FLUTTER AND OTHER VIBRATIONAL LOADS, WHILE MAINTAINING STRAIN COMPATIBILITY BETWEEN SUBSTRATE PANEL AND HCF
5. SHED AIRFLOW-NO EXPOSED EDGES TO FACE FLOW.
6. ~ RAIN.
7. ACCOMMODATE CONTRACTION AND EXPANSION OF STRUCTURE AND TPS WITH MINIMUM GAPS.
8. ACCOMODATE OR AVOID WEAR OF RUBBING SURFACES.
9. MAINTAIN AERODYNAMIC SHAPE.
10. CONTROL AIR LEAKAGE BETWEEN PANELS
   a. PURGE
   b. VENTING

B. DESIGN IMPLEMENTATION
1. ACCOMODATE ANTENNAS AND PENETRATIONS.
2. STANDARDIZE PANEL SIZES, CONFIGURATIONS AND ATTACHMENTS AS MUCH AS POSSIBLE.
3. SEAL DOORS
   a. TPS MUST NOT BIND DOORS AFTER ENTRY
4. LIMITED SIZE AND WEIGHT FOR EASY HANDLING.
5. MUST BE INTERCHANGEABLE.
6. PANELS MUST BE QUICKLY REMOVEABLE
   a. NO SEQUENTIAL ORDER OF INSTALLATION
7. SEALS MUST NOT BE EASILY DAMAGED DURING REMOVAL AND INSTALLATION
8. ACCOMODATE REPLACEMENT OF HCF WITH ABLATORS.





TPS PANEL SUMMARY

LOCATION	FLAT	SINGLE CURVE	DOUBLE CURVE	TOTAL
DORSAL FIN OUTBOARD SURFACE	—	118	—	118
" INBOARD SURFACE	—	118	—	118
VENTRAL FIN OUTBOARD SURFACE	—	120	—	120
" INBOARD SURFACE	—	114	—	114
WING LOWER SURFACE	536	92	—	628
" UPPER SURFACE	54	332	—	386
CANARD LOWER SURFACE	—	180	—	180
" UPPER SURFACE	—	92	—	92
BODY NOSE SURFACE			36	36
" FOREBODY SURFACE		28	562	590
" CONSTANT SECT SURFACE	92	1266	46	1404
" AFT SECT SURFACE	316	70	522	908
TOTAL	998	2530	1166	4694

TOTAL SURFACE AREA COVERED BY HCF	39,675	SQ FT
FILLETS AND CREW COMPARTMENT	1,188	SQ FT
TPS PANEL AREA	38,487	SQ FT
AVERAGE PANEL AREA	82	SQ FT

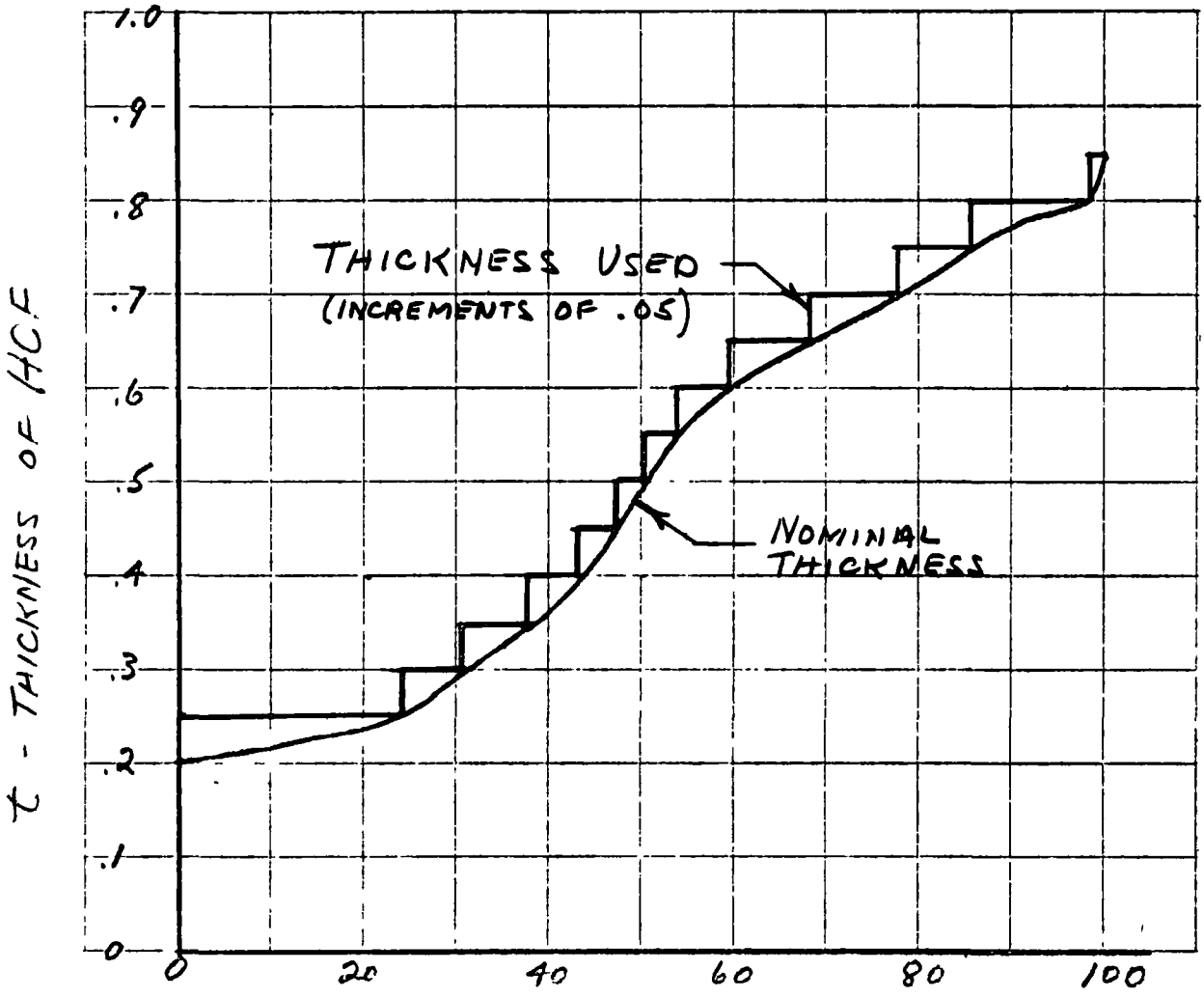
MARTIN MARIETTA CORPORATION

BOOSTER OVERALL TPS ASSEMBLY CONFIGURATION 20A

04236 899A2010642

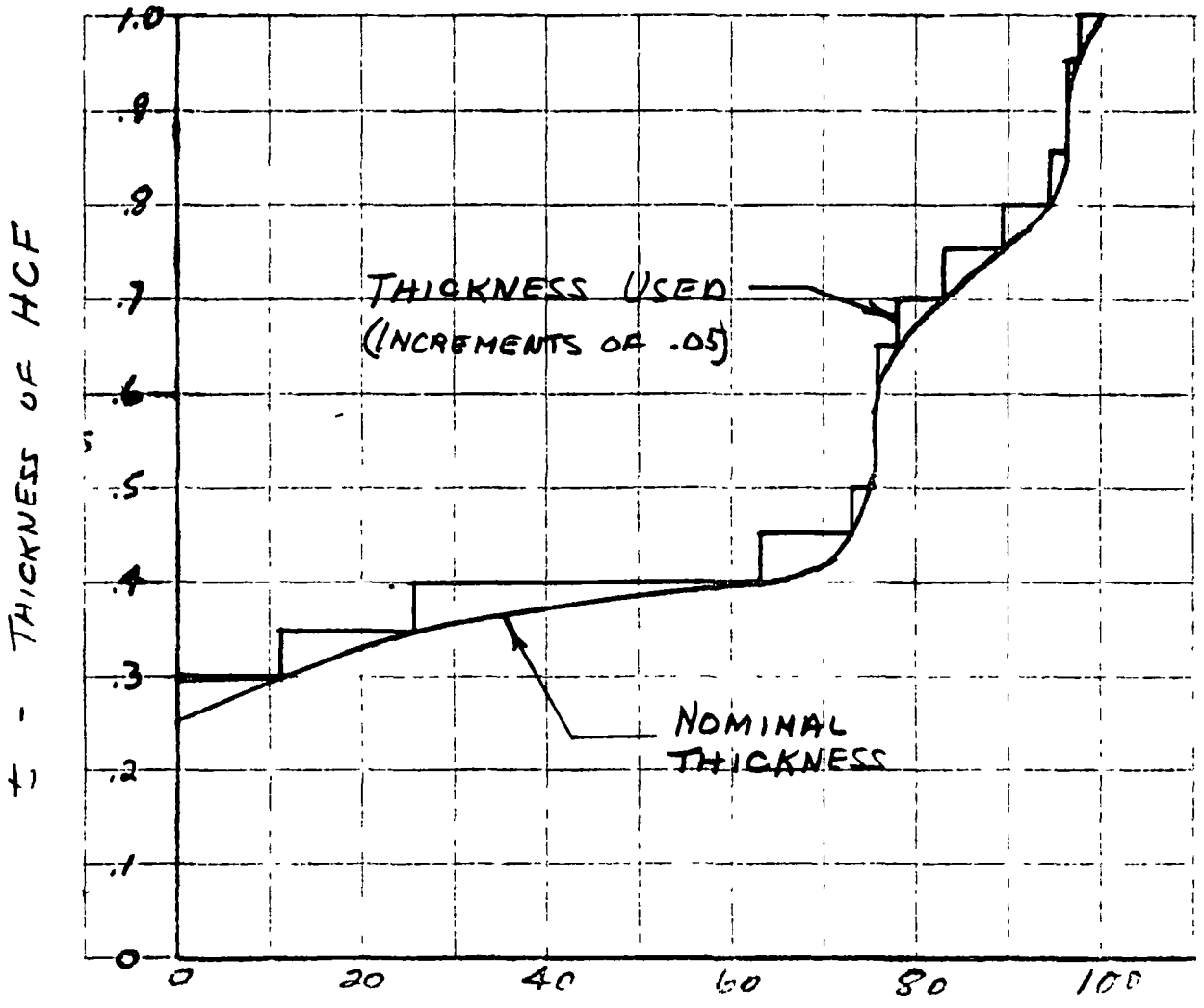
WING HCF

THICKNESS VS PERCENT AREA



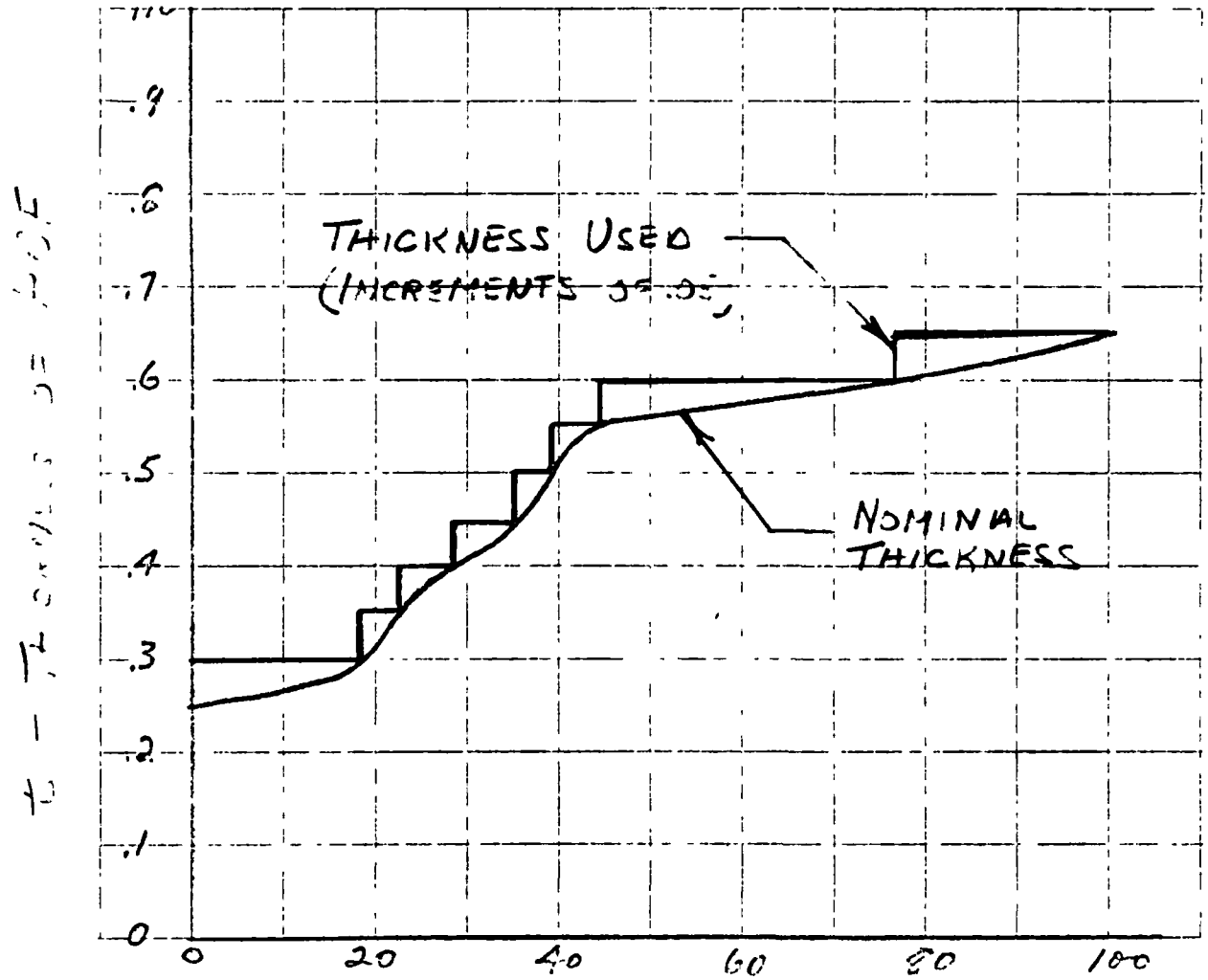
FIN HCF

THICKNESS VS PERCENT AREA



CANARD HC =

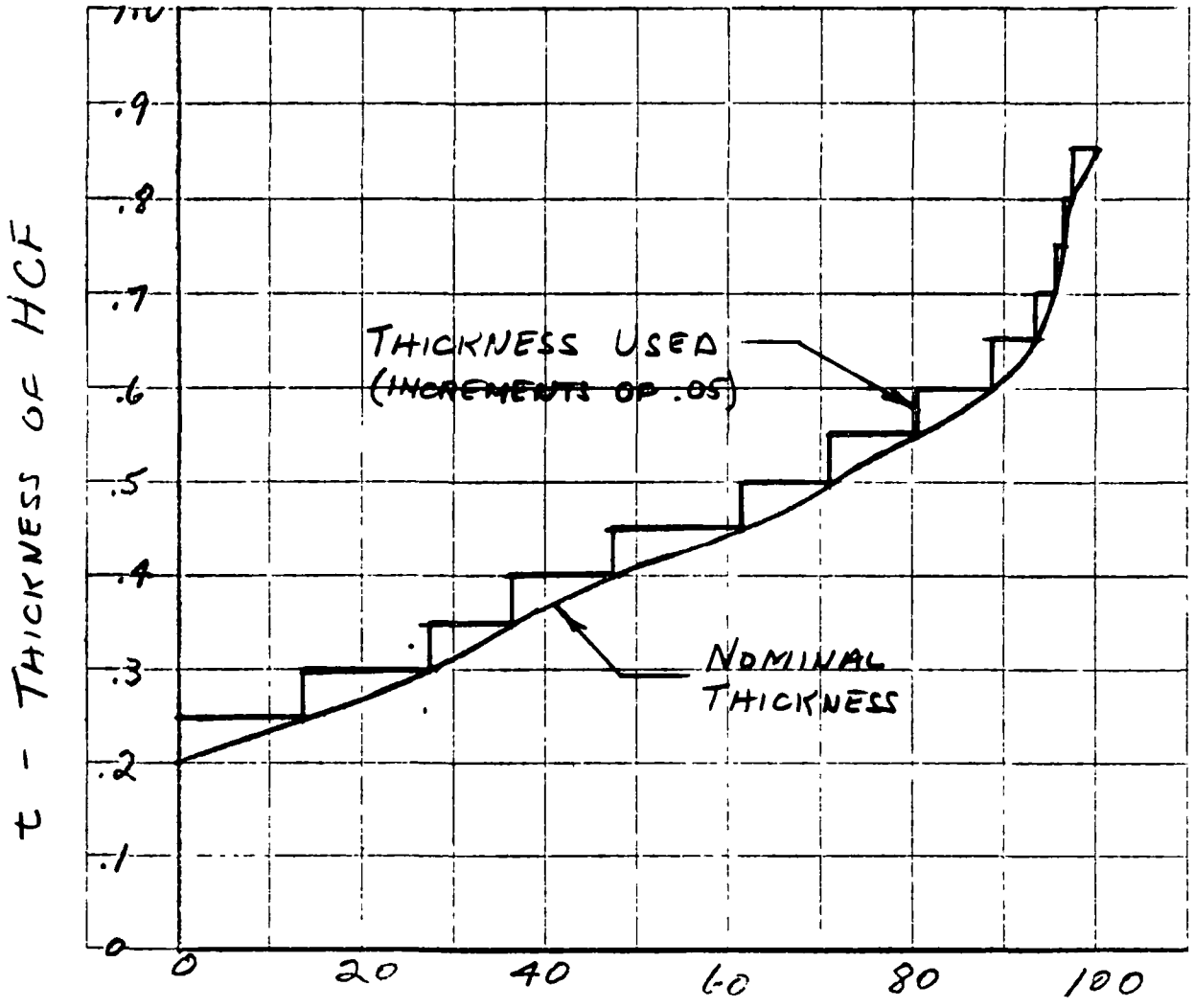
T- C- 1552 VS PERCENT AREA



PERCENTAGE OF CANARD AREA
NEEDING LESS THAN t

BODY HCF

THICKNESS VS PERCENT AREA



TPS WEIGHT CALCULATION

(WT = AREA x AREA RATIO x UNIT WT.)

WING						16150
UPPER STRUCTURE						
SUPPORTS	39824	x .1015	x 3598	=	1455	
RAILS		x .1015	x 0645	=	261	
SUBPANEL (HC)		x .026	x .405	=	419	
		x .0525	x .533	=	1115	
		x 008	x .580	=	185	
		x 006	x 722	=	173	
		x .009	x .865	=	358	
LOWER STRUCTURE						
SUPPORTS		x .1015	x .4004	=	1619	
RAILS		x .1015	x .0645	=	261	
SUBPANEL (HC)		x 048	x .312	=	603	
		x .0125	x .360	=	179	
		x [illegible]	x .408	=	260	
		x [illegible]	x 456	=	445	
		TOTAL STRUCTURE				7[illegible]3
HCF						
T = 25	8081	x .232	x 313	=	587	
30		x 064	x 375	=	194	
[illegible]		x 071	x 4[illegible]	=	251	
40		x .0[illegible]	x .[illegible]	=	230	
4		x 040	x .563	=	182	
[illegible]		x 032	x .625	=	162	
[illegible]		x 037	x .6[illegible]	=	205	
[illegible]		x 0[illegible]	x .750	=	357	
6		x 088	x 812	=	577	
70		x 096	x .[illegible]	=	679	
[illegible]		x 080	x .93[illegible]	=	606	
80		x [illegible]	x 1.000	=	1018	
85		x .01[illegible]	x 1.063	=	155	
		TOTAL HCF				[illegible]
COATING						
WETTED	8081	x .240		=	19[illegible]9	
EDGE	8081	x .165 (.51 - .125)		=	[illegible]	
		TOTAL COATING				[illegible]451
BOND						
	8081	x .180		=	14[illegible]	
		TOTAL BOND				14[illegible]

[illegible]

DEN 066037 (3-57)

TP WEI - CALC / AT) (CO I -)
(WT ANGL X ANGL +) X UNI - WT)

FIN 6576

UPPER INBD STRUCTURE

SUPPORTS	39828	X .02 25 \	4004	=	331
RAILS		X 0212 5 X	06 1	=	55
SUBPANEL (H-)		X 0152 X	312	=	127
		X .002 5 X	.4	=	40
		X 0037 X	533	=	121
		X 0010 X	~	=	23
		X 0032 X	.722	=	23
		X 0010 X	.66	=	40

UPPER OUTBD STR.

SUPPORTS		X 021 X	7 1	=	331
RAILS		X .0212 X	1		55
SUBPANEL (HC)		X .0 25 X	31	=	1-7
		X .0 2 5 X	363	=	39
		X 0 3 5 X	40	=	53
		X .0 50 X	.7	=	91

LOWER OUTBD STR

SUPPORTS		X .0212 \	4004	=	331
RAILS		X .0 2 X	06	=	5
SUBPANEL (H-)		X 01 2 X	31	=	127
		X .0 X	.4 5	=	40
		X .0 X	1	=	121
		X 5 X	.2	=	2
		X .0 3 X	722	=	23
		X .0 3 X	1 003	=	40

LOWER INBD STR

SUPPORTS		X 1 X	7004	=	334
RAILS		X 0212 X	1	=	55
SUBPANEL (HC)		X 0152 X	312	=	127
		X 0 47 X	.36	=	37
		X 103 X	4	=	53
		X 0 X	7	=	71

TOTAL STRUCTURE 2177

TPS WEIGHT CALCULATION (CON'T)
(WT = AREA x AREA RATIO x UNIT WT)

FIN (CON'T)

HCF

t = .30	3375	x .113	x .375	=	143
.35		x .144	x .438	=	213
.40		x .375	x .500	=	632
.45		x .099	x .563	=	188
.50		x .025	x .625	=	53
.65		x .025	x .812	=	69
.70		x .0[illegible]	x .875	=	148
.75		x .064	x .938	=	203
.80		x .0[illegible]	x 1.00[illegible]	=	1[illegible]
.85		x .020	x 1.063	=	72
.95		x .010	x 1.188	=	40
1.00		x .025	x 1.2[illegible]	=	105

TOTAL HCF 203[illegible]

COATING

WETTED	3375 x .[illegible]	=	810
EDGES	3375 x .1[illegible] (.4 [illegible])	=	199

TOTAL COATING 1009

BOND

3375 x .1[illegible] = 608

TOTAL BOND 608

DEN 066037 (3-57)

TPS WEIGHT CALCULATION (CON'T)
(WT = AREA x AREA RATIO x UNIT WT)

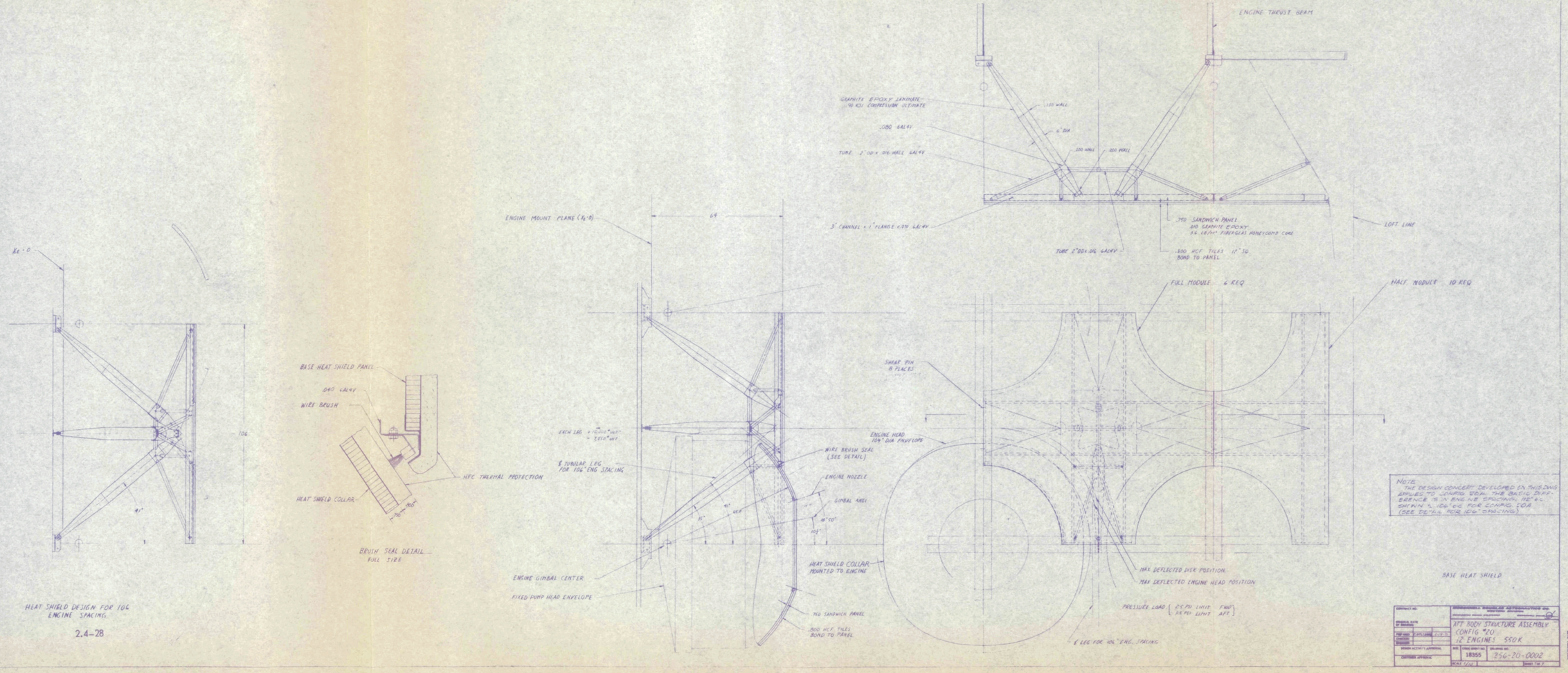
CANARD						4524
UPPER STRUCTURE						
SUPPORTS	3482	x .0290	x .3598	=	415	
RAIL		x .0290	x .0645	=	74	
SUBPANEL (HC)		x .0145	x .3120	=	180	
		x .0040	x .374	=	60	
		x .0045	x .317	=	93	
		x .0060	x .546	=	142	
LOWER STR						
SUPPORTS		x .0290	x .4004	=	461	
RAIL		x .0290	x [illegible]	=	74	
SUBPANEL (HC)		x .0145	x .3120	=	205	
		x .0[illegible]	x .360	=	86	
		x .0[illegible]	x .[illegible]	=	57	
		x .0040	x .4[illegible]	=	73	
		TOTAL STRUCTURE				1120
HCF						
τ = .30	2301	x .184	x .375	=	159	
.35		x .042	x .438	=	42	
.40		x .059	x .500	=	68	
.45		x .064	x .563	=	83	
.50		x .041	x .625	=	59	
.55		x .0[illegible]	x .6[illegible]	=	87	
.60		x .320	x .750	=	552	
.65		x .235	x .812	=	431	
		TOTAL HCF				1481
COATING						
WETTED	2301	x .240		=	552	
EDGES	2301	x .165 (518 - .125)		=	149	
		TOTAL COATING				101
BOND						
	2301	x .180		=	414	
		TOTAL BOND				414

DEN 066037 (3-57)

TPS WEIGHT CALCULATION (CON'T)
(WT = AREA X AREA RATIO X UNIT WT)

BODY						47101
UPPER STRUCTURE						
SUPPORTS	29828	X .287	X .3598	=	4113	
RAILS		X .287	X .117	=	1337	
SUBPANEL (HC)		X .287	X .312	=	3566	
UPPER FWD STR.						
SUPPORTS		X .043	X .3598	=	616	
RAILS		X .027	X .156	=	168	
		X .016	X .234	=	149	
SUBPANEL (HC)		X .027	X .524	=	563	
		X .016	X .627	=	399	
LOWER STR						
SUPPORTS		X .324	X 4004	=	5167	
RAILS		X .324	X .0645	=	832	
SUBPANELS (HC)		X 130	X .312	=	1615	
		X .124	X 327	=	1615	
		X .060	X 376	=	899	
		X 010	X 408	=	162	
		TOTAL STRUCTURE				21201
HCF						
τ = 25	26071	X 147	X .313	=	1200	
30		X .139	X .375	=	1359	
.35		X 092	X .438	=	1050	
40		X .109	X .500	=	1421	
45		X .130	X .563	=	1968	
50		X .075	X .625	=	1348	
.55		X .093	X .688	=	1668	
60		X .080	X .750	=	1564	
.65		X .047	X .812	=	995	
70		X .020	X .875	=	456	
75		X .010	X .938	=	245	
80		X .010	X 1.000	=	260	
.85		X .028	X 1.063	=	775	
		TOTAL HCF				14449
COATING						
WETTED	26071	X .240		=	6257	
EDGES	26071	X .165(.443-.125)		=	1369	
		TOTAL COATING				7626
BOND						
	26071	X .180		=	4693	
		TOTAL BOND				4693

DEN 066037 (3-57)


ENGINE THRUST BEAM
GRAPHITE EPOXY LAMINATE
.080 GAL4V
TUBE 2" OD x .016 WALL GAL4V
.150 WALL
6" DIA
.200 WALL
3" CHANNEL x 1" FLANGE x .070 GAL4V
.750 SANDWICH PANEL
.010 GRAPHITE EPOXY
5.6 LB/FT³ FIBERGLAS HONEYCOMB CORE
TUBE 2" OD x .016 GAL4V
.800 HCF TILES 12" SQ
BOND TO PANEL
LOFT LINE
ENGINE MOUNT PLANE (Xe-0)
64
FULL MODULE 6 REQ
HALF MODULE 10 REQ
SHEAR PIN
8 PLACES
ENGINE HEAD
104" DIA ENVELOPE
WIRE BRUSH SEAL
(SEE DETAIL)
ENGINE NOZZLE
GIMBAL ANGLE
℄ TUBULAR LEG
FOR 106" ENG SPACING
HEAT SHIELD COLLAR
MOUNTED TO ENGINE
ENGINE GIMBAL CENTER
FIXED PUMP HEAD ENVELOPE
.750 SANDWICH PANEL
.800 HCF TILES
BOND TO PANEL
MAX DEFLECTED DISK POSITION
MAX DEFLECTED ENGINE HEAD POSITION
PRESSURE LOAD
℄ LEG FOR 106" ENG. SPACING
BASE HEAT SHIELD
Xe-0
106
41°
BASE HEAT SHIELD PANEL
.040 GAL4V
WIRE BRUSH
HFC THERMAL PROTECTION
HEAT SHIELD COLLAR
BRUSH SEAL DETAIL
FULL SIZE
HEAT SHIELD DESIGN FOR 106
ENGINE SPACING
NOTE
THE DESIGN CONCEPT DEVELOPED ON THIS DWG
APPLIES TO CONFIG 20A. THE BASIC DIFF-
ERENCE IS IN ENGINE SPACING, 112" o.c.
SHOWN & 106" o.c. FOR CONFIG 20A
(SEE DETAIL FOR 106" SPACING)
AFT BODY STRUCTURE ASSEMBLY
CONFIG #20
12 ENGINES 550K
18355
256-20-0002

DETAIL WEIGHT SUMMARY

THERMAL PROTECTION SYSTEM

BASE HEAT PROTECTION — 5676 LB

	WEIGHT
BASE HEAT PANELS STA 3862	[3138]
NOZZLE MOUNTED DISKS	1350
INTERIOR PANELS	585
SIDE PANELS	496
CORNER PANELS	92
BRUSH SEAL ASSY	615
SUPPORT STRUCTURE	[1525]
MAIN STRUTS	255
SECONDARY STRUTS	63
CHANNELS (PANELS)	126
MAIN STRUT SUPT BRACKET	37
SEC. STRUT ATTACH FITTINGS	12
PERIMETER SUPT ANGE	107
PANEL EDGE SUPPORT	25
BOAT TAIL PANELS	[1615]
ATTACHING PARTS	[260]

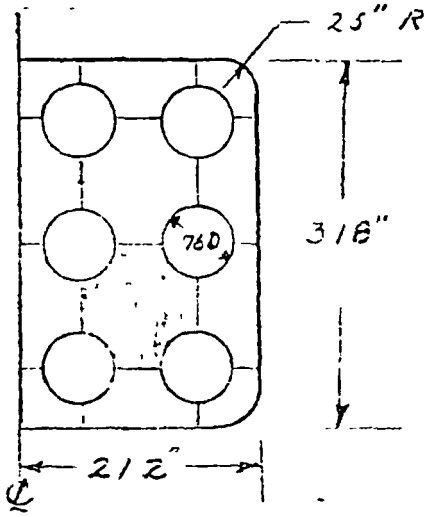
UNIT WEIGHT = $\frac{5078}{1156+13}$ = 4.34 PSF

BASE HEAT SHIELD

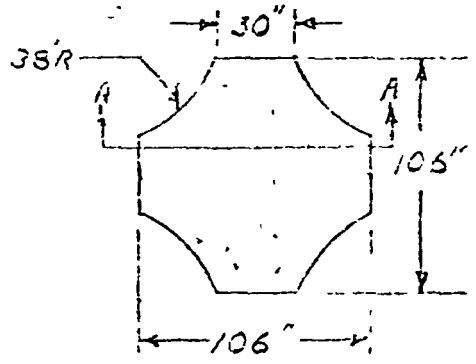
TOTAL BASE HEAT SHIELD AREA :

$A = 424(318) - 4(2146)25^2 - 12\pi/4(76)^2 = 79{,}986 \text{ IN}^2$

$= 555.5 \text{ FT}^2$

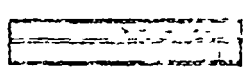


TYPICAL PANEL



AREA = $106(106) - \pi(38)^2 = 6{,}710 \text{ IN}^2$

EDGE LENGTH = $4(30) + 2\pi(38) = 359 \text{ IN}$

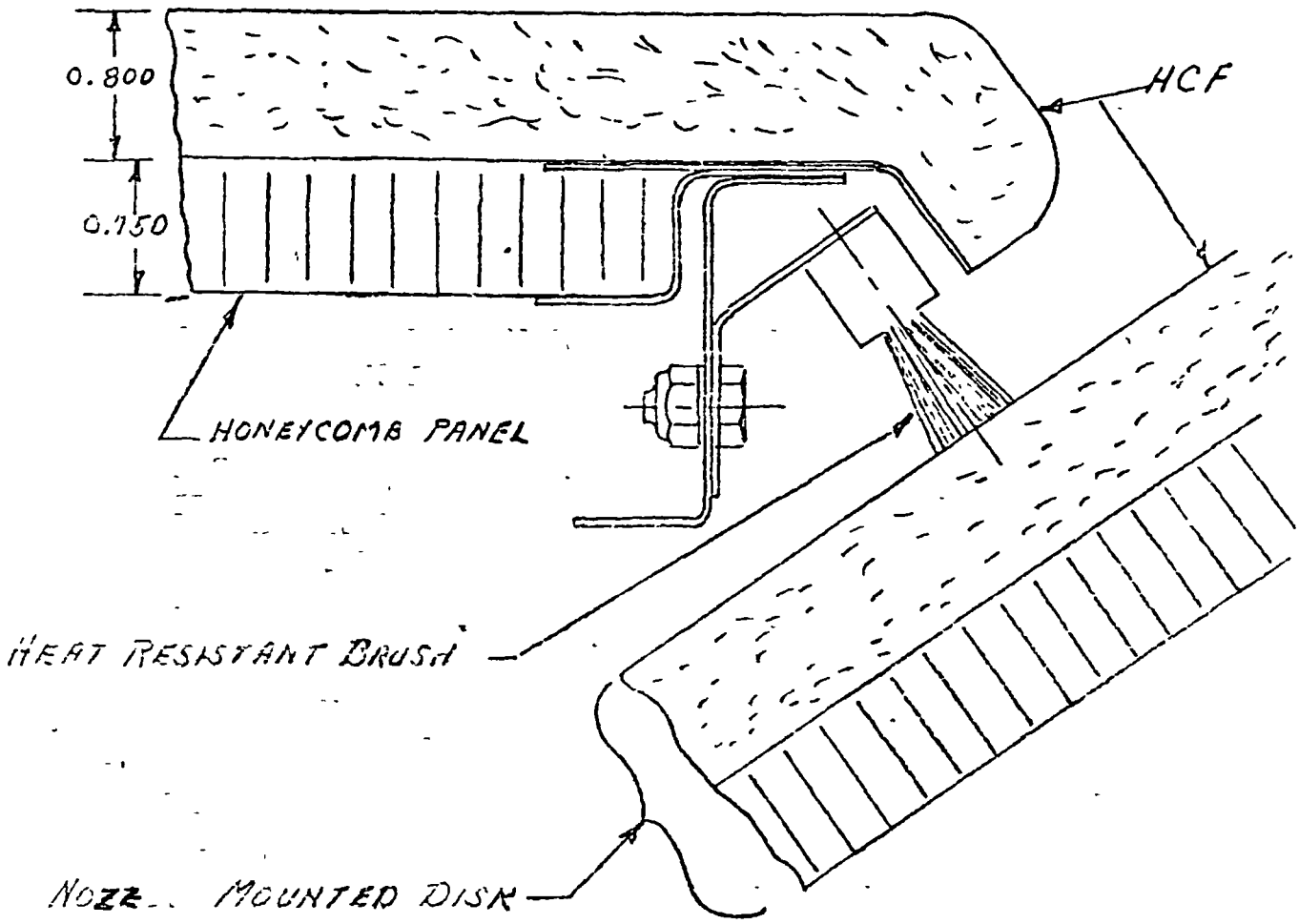


A-A

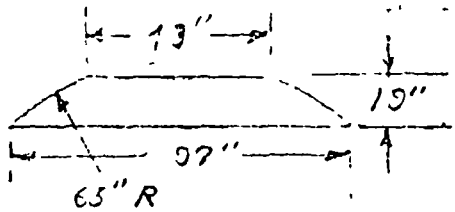
BREAKDOWN OF SECTION A-A TOP TO BOTTOM

COATING ON TOP OF HCF	=	240 LB/FT²
HCF 0.8" THICK @ 15 LB/FT³	=	1.000 LB/FT²
BOND	=	.1[illegible] LB/FT²
GRAPHITE EPOXY 0.010" THICK @ 0.055 LB/IN³	=	.075 LB/FT²
ADHESIVE	=	.100 LB/FT²
FIBERGLAS HONEYCOMB 0.73" THICK @ 3.6 LB/FT³	=	.219 LB/FT²
ADHESIVE	=	.100 LB/FT²
GRAPHITE EPOXY 0.010" THICK @ 0.055 LB/IN³	=	.073 LB/FT²
TOTAL PANEL LESS EDGE CHANNELS	=	1.997 LB/FT²

TYPICAL HONEYCOMB PANEL EDGE CHANNEL & BRUSH SEAL SUPPORT BRACKET



NOZZLE MOUNTED DISK



AREA = 2π65(19) = 7,760 IN² = 53.8 FT²

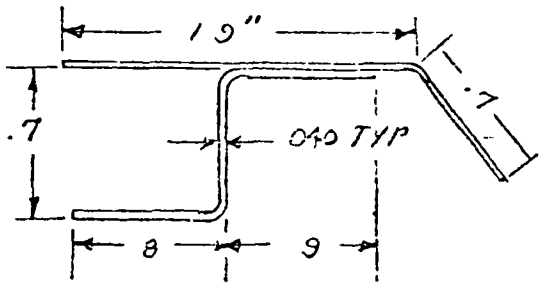
EDGE LENGTH = π(97+43) = 440 IN

DISK WT - 12 REQUIRED

PANEL WT = 53.8(1.997)	-	107.6	LB
EDGE CHANNEL = 440(.011)	=	4.9	LB
WT / PANEL	=	112.5	LB

TOTAL FOR 12 DISKS = 12(112.5) = 1350 LB

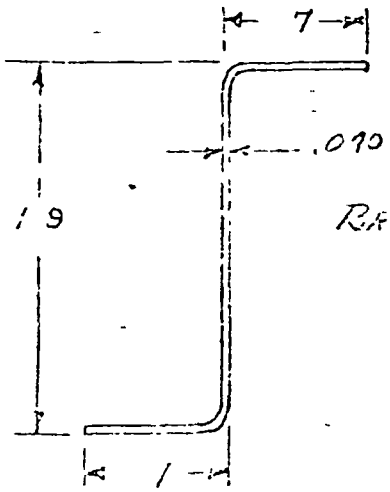
HONEYCOMB PANEL EDGE CHANNEL



CHANNEL MADE FROM GRAPHITE EPOXY - 0.055 LB/IN^3

CHANNEL WT = $(19 + .7 + .7 + .7 + 5.0)(.040)(1)(.055)$ = 0.011 LB/IN

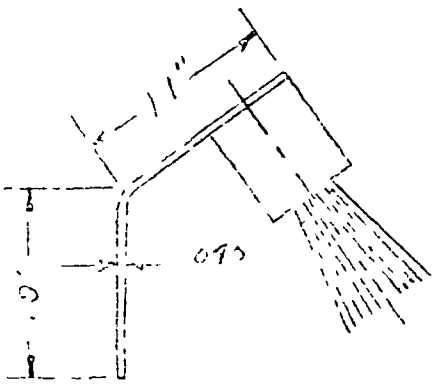
BRUSH SEAL SUPPORT BRACKET



MATERIAL : TITANIUM - 0.161 LB/IN^3

BRACKET WT = $(.7 + 1.9 + 3.3 + .7)(.040)(.161)$ = .0243 LB/IN

BRUSH SEAL & SUPPORT ANGLE



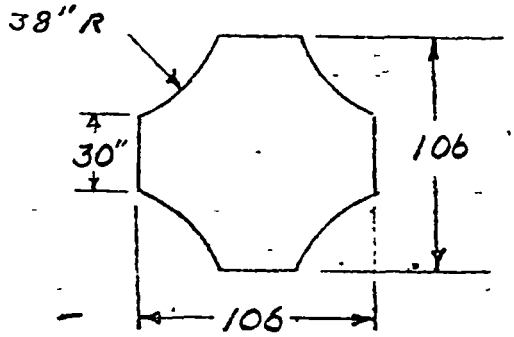
MATERIAL : TD NI 0.322 LB/IN^3

BRUSH WT = 2 LB/FT = 0.167 LB/IN

ANGLE WT = $(1.1 + .9)(.040)(.322)$ = 0.0255 LB/IN

TOTAL WT - BRUSH & ANGLE = 0.1925 LB/IN

INTERIOR PANELS - 6 REQ

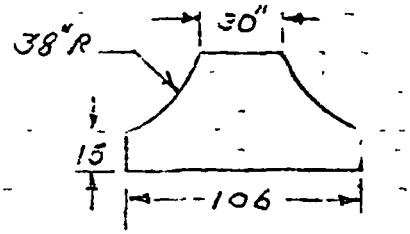


AREA = 106(106) - π(38)² = 6,710 IN² = 46.7 FT²

EDGE LENGTH = 4(30) + 2π38 = 359 IN

WT = 6[(46.7)(1.997) + 359(0.0110)] = 6(93.5 + 4.0) = 585 LB

UPPER, LOWER & SIDE PANELS - 10 REQUIRED

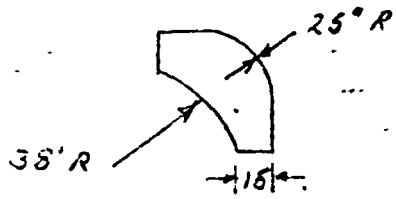


AREA = 23.35 FT²

EDGE LENGTH = 2(30) + π(30) + 106 = 260"

WT = 10[(23.35)(1.997) + 260(0.0110)] = 10(46.7 + 2.9 496.3

CORNER PANELS - 4 REQ



AREA = 53(53) - π/4(38)² - .2146(25)² = 1,544 IN²
= 10.8 FT²

EDGE LENGTH = 2(15) + π/2(38 + 25) = 129"

WT = 4[108(1.997) + 129(0.0110)] = 4(21.6 + 1.42) = 92.1 LB

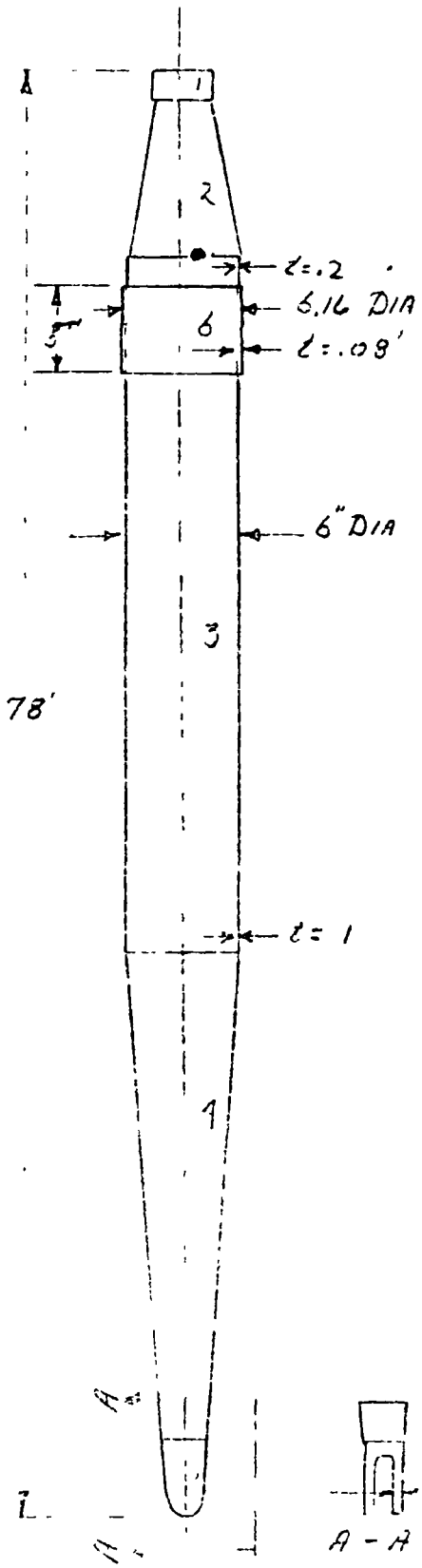
BRUSH SEAL AND SUPPORT BRACKET - 12 REQUIRED

WT OF SEAL + BRACKET = 0.213 + .1528 = 0.2141 LB/IN

LENGTH REQUIRED = 2π(38) = 239 IN PER ENGINE

TOTAL WT = 12(239)(.2141) = 615 LB

MAIN SUPPORT STRUT – BASE HEAT PANEL – APPROXIMATE



$A = \pi D \ell$

$A_1 = \pi(3.2)(1.75)$	=	17.6 IN²
$A_2 = \pi(4.6)(6.6)$	=	124.1 IN²
$A_3 = \pi(6)(37.6)$	=	708.0 IN²
$A_4 = \pi(4)(26.75)$	=	336.0 IN²
$A_5 = 2[2.25(3) + \pi/2(1)^2]$	=	3.2 IN²
$A_6 = \pi(6.16)(5)$	=	96.6 IN²

MATERIAL · GRAPHITE PHENOLIC LAMINATE

	A	ℓ	ρ	
WT_1	17.6	.25	.055	= 242
WT_2	124.1	.2	.055	= 1.370
WT_3	708.0	.15	.055	= 5.810
WT_4	336	.1	.055	= 1.848
WT_5	3.2	.25	.055	= 044
WT_6	96.6	.08	.161	= 1.296 *
	TOTAL/STRUT			10.536 LB

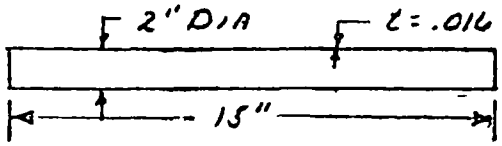
TOTAL FOR 6 PANELS

$WT = 24(10.6) =$ 255 LB

* TITANIUM

SECONDARY SUPPORT STRUTS - BASE HEAT PANEL

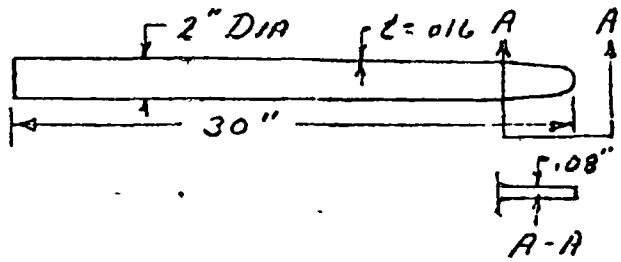
2" DIA STRUT 15" LONG - 4 REQ/PANEL - 24 TOTAL



TITANIUM

$WT = 24\pi D t \ell \rho = 24\pi(2)(15)(.016)(.161) \simeq .$ ∴ 6 LB

2" DIA STRUT 38" LONG - 8 REQ/PANEL - 48 TOTAL

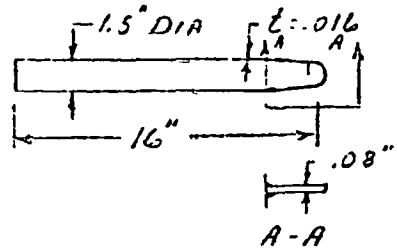


TITANIUM

$WT = 8\{\pi(2)(26)(.016)(.161) + [1.5(3) + \pi/2(1)^2](.08)(.161)\} =$

$= 48[.42 + .08] =$ 24 LB

1.5" DIA STRUT 16" LONG - 8 REQ/PANEL - 48 TOTAL

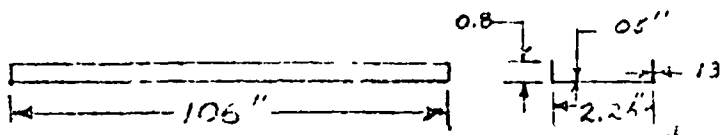


TITANIUM

$WT = 8\{\pi(1.5)13(.016)(.161) + [1.25(2) + \pi/2(1)^2](.08)(.161)\}$

$= 48(.16 + .05) =$ 10 LB

PANEL MOUNTED CHANNELS - 4 REQ/PANEL - 24 TOTAL



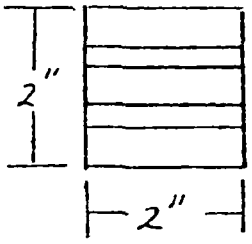
TITANIUM
t = .07"

VOLUME = $106[(2)(.05) + 2(.8)(.13)] = 32.7$ IN³/CHANNEL

$WT = 24(32.7)(.161) =$ 126 LB

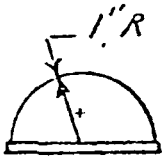
FITTINGS (USE FOR ALL 2" & 1.5" DIA STRUTS)

140 REQUIRED



TITANIUM : t = .07"

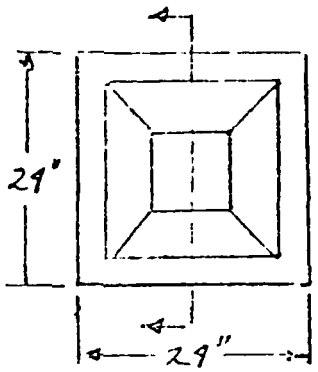
AREA = 2×2 + π(1)² = 7.14 IN²

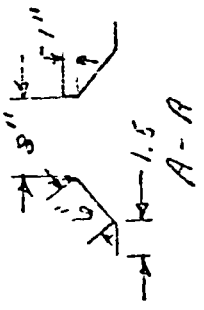


WT = 7.14(.07)(.161) = 0.08 LB/FITTING

TOTAL WT = 140(.08) = 12 LB

MAIN STRUT SUPPORT BRACKET - 6 REQUIRED



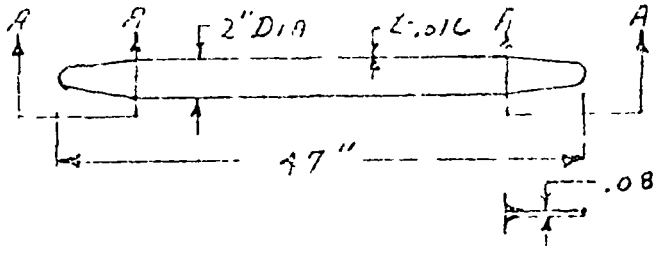


TITANIUM : t = .07"

AREA = 1.5(18 + 42) + 4(6)(8 + 21)/2 + 64 = 135 + 348 + 64 = 547 IN²

WT = 6[547(.07)(.161)] = 37 LB

TOP BOTTOM SIDE & CORNER SUPPORT STRUT - 28 REQUIRED



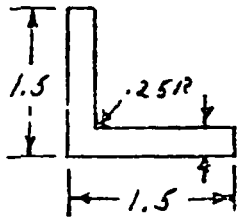
TITANIUM

WT = π(2)(3)(.016)(.161) + 2[(1.5)(3) + π/2(1)²].08(.161)

= 28[.632 + 16] = 23 LB

TOP, BOTTOM, SIDES & CORNER SUPPORT ANGLE

MATERIAL : TITANIUM



AREA = (1.5+1.25)(.25) + .0134 = .702 IN²

LENGTH = 1510 IN

WT = .702(1510)(.101) = 107 LB

PANEL STRAIGHT EDGE SUPPORT

THE SAME TITANIUM "Z" USED TO SUPPORT THE BRUSH SEAL IS USED ALONG THE STRAIGHT INTERIOR EDGES OF ALL PANELS

LENGTH REQUIRED:

INTERIOR PANELS

L = 6 [4(30)] = 720"

UPPER, LOWER, SIDE & CORNER PANELS

L = 10[2(15)] + 4[2(15)] = 420"

WT = 1,140(0.0213 LB/IN) = 25 LB

ATTACH PARTS & MISC

PANEL MOUNTED CHANELS

BOLT & INSERT - WT = 4[22(.04)] = 3.5 LB/PANEL

EDGE SUPPORT Z

BOLT & INSERT = .04/4 = .01 LB/IN

PERIMETER LENGTH = 359 IN

WT = 359(.01) = 3.6 LB/PANEL

TUBULAR SUPPORT & BRACKET ATTACH

WT - 8(.2 LB-EA) + 120(.01) = 2.8 LB/PANEL

3.9 LB/PANEL

USE 10 LB/PANEL

EACH PANEL IS 46.7 FT²

ATTACHMENTS = 10.0/46.7 = 0.214 LB/FT²

TOTAL AREA = (79,986 + 108,200)/144 = 1,310 FT²

TOTAL WT ATTACH PARTS & MISC:

WT = 1,310(.214) = 280 LB

HEAT SHIELD PANELS ON INSIDE OF BOAT TAIL

PANELS ARE ATTACHED TO INSIDE SURFACE OF THE BOAT TAIL FROM STA. 3863 TO STA. 3935

$AREA = 2(328 + 421)72 = 108{,}200\ IN^2 = 763\ FT^2$

PANEL WT = 0.0151 LB/IN² (SEE NEXT PAGE)

$WT = A \times UNIT\ WT = 108{,}200(0.0151) = \underline{1635\ LBS}^*$

* REFLECTS 106" ENGINE SPACING CONFIGURATION

BASE HEAT SHIELD

HCF (HARD COMPACT FIBER)

.80" t @ 15 LB/FT³	1.000	LB/FT²
COATING (MARTIN MARIETTA INFO)	.240	LB/FT²
BOND (MARTIN MARIETTA INFO)	.180	LB/FT²
UNIT WT OF HCF INSTALLED	1.420	LB/FT²

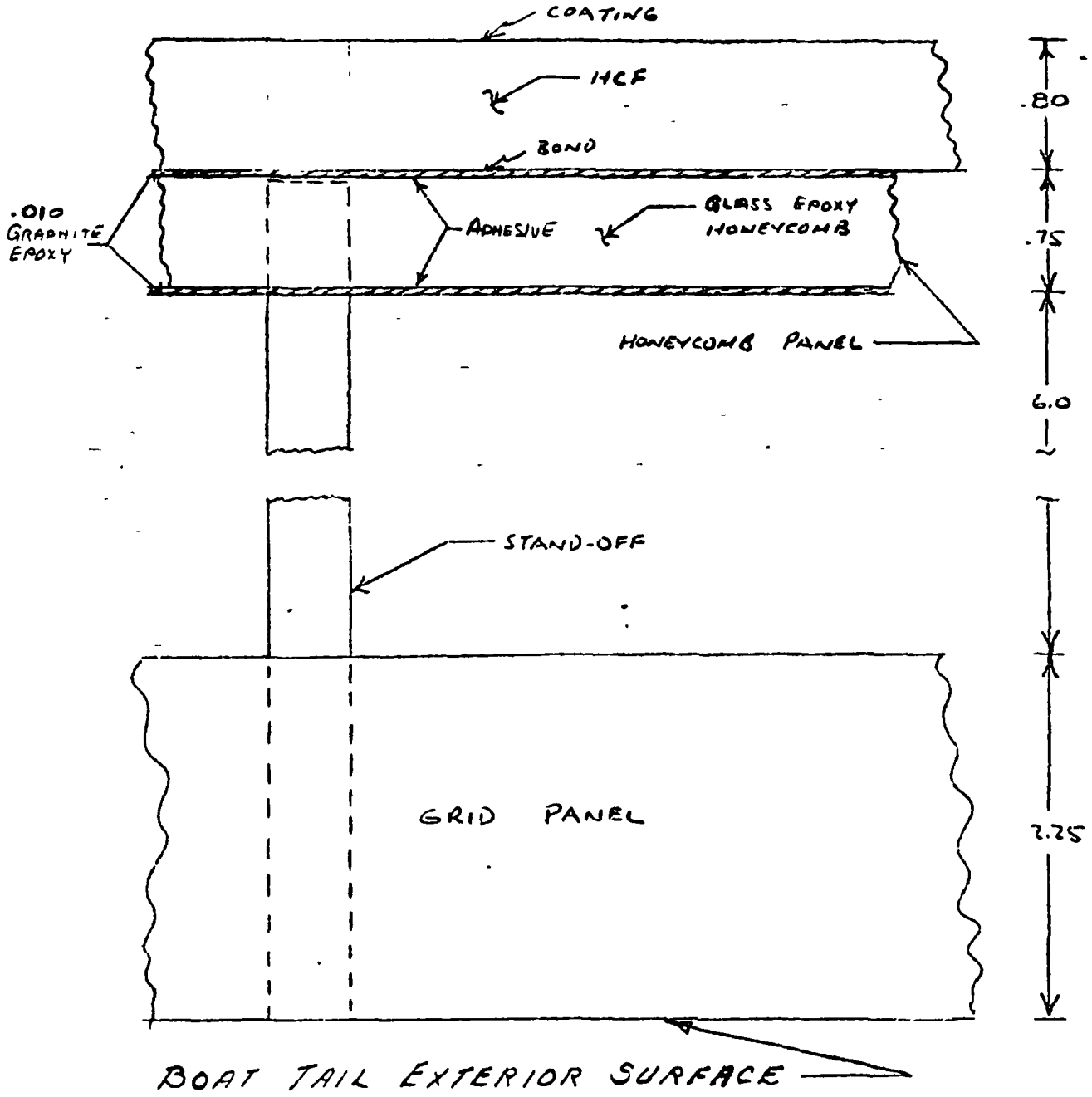
HONEYCOMB PANEL (.75" t)

FIBERGLAS HONEYCOMB		
.750" – .020" = .730" t @ 3.6 LB/FT³		
UNIT WT = (.73IN X 1 FT/12 IN X 3.6 LB/FT³)	.219	LB/FT²
GRAPHITE EPOXY (MARTIN-MARIETTA INFO)		
2 FACE @ .018"t/SA @ .055 LB/IN³		
UNIT WT = (.020 IN X .055 LB/IN³ X (144 IN²/1 FT²))	.158	LB/FT²
ADHESIVE		
2 LAYERS @ .2 LB/FT² (2 LAYERS)	.200	LB/FT²
EDGING (EST UNIT WT)	.170	LB/FT²
UNIT WT OF HONEYCOMB PANEL	.747	LB/FT²

SUMMARY OF BASE HEAT SHIELD

HCF INSTALLED	1.420 LB/FT²
HONEYCOMB PANEL	.747 LB/FT²
TOTAL UNIT WT	2.167 LB/FT² OR .0151 LB/IN²

BASE HEAT SHIELD
ATTACHED TO INSIDE OF BOAT TAIL SUPT FITTINGS



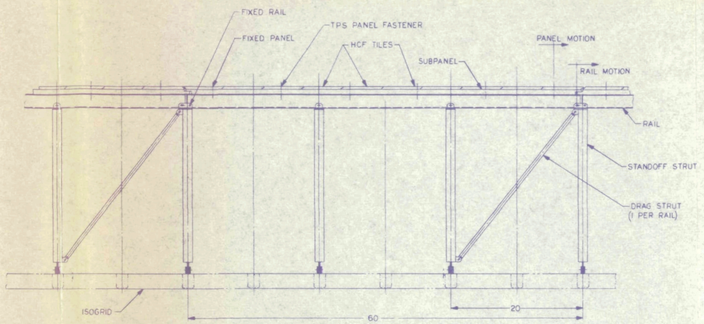
WEIGHT SUMMARY

THERMAL PROTECTION SYSTEM

STAND-OFFS

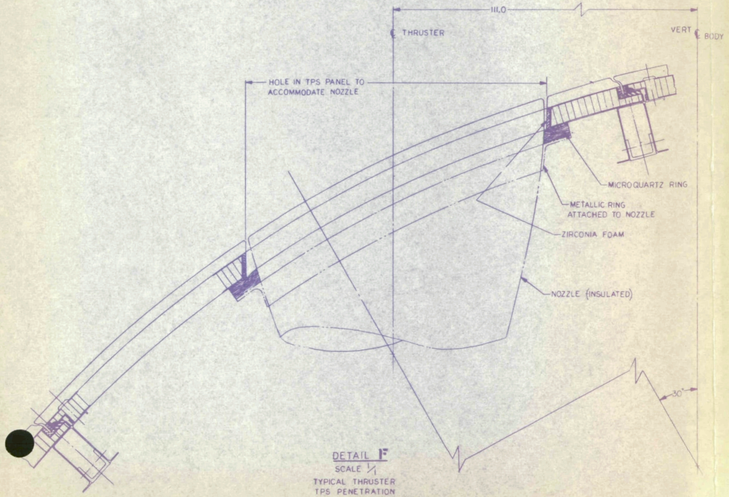
3327

	AREA FT²	UNIT WT LB/FT²	WEIGHT LB
LOX LINE	2440	.197	479
AFT LH_2 TANK	1900	.748	1425
THRUST STRUCTURE	1353	.563	761
CANARD FILLET	202	.850	172
CANARD/BODY BOTTOM	180	1.120	202
WING FILLET	300	.550	166
WING - UPPER C.T.	627	.195	122

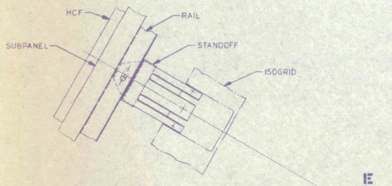


B–B ROTATED 35° CW

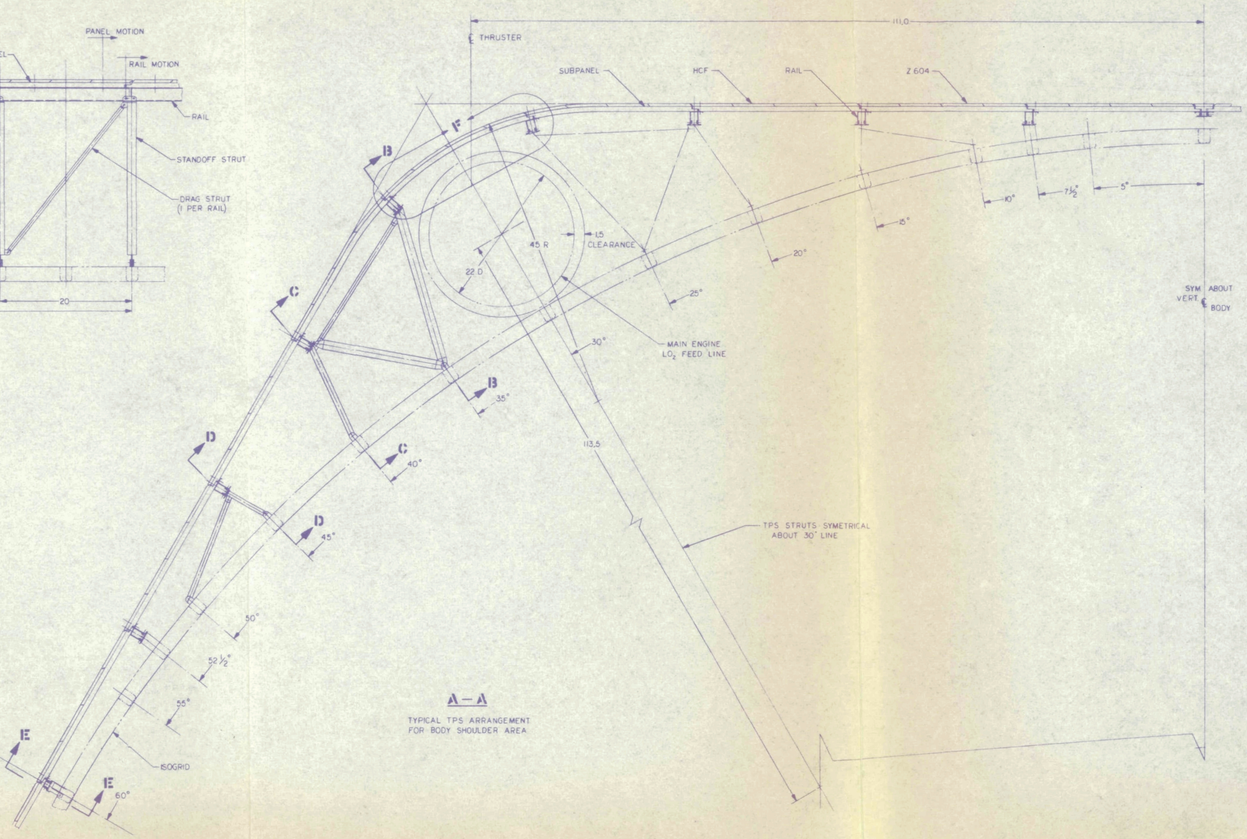
C–C & D–D SIMILAR



DETAIL F
SCALE 1/1
TYPICAL THRUSTER TPS PENETRATION



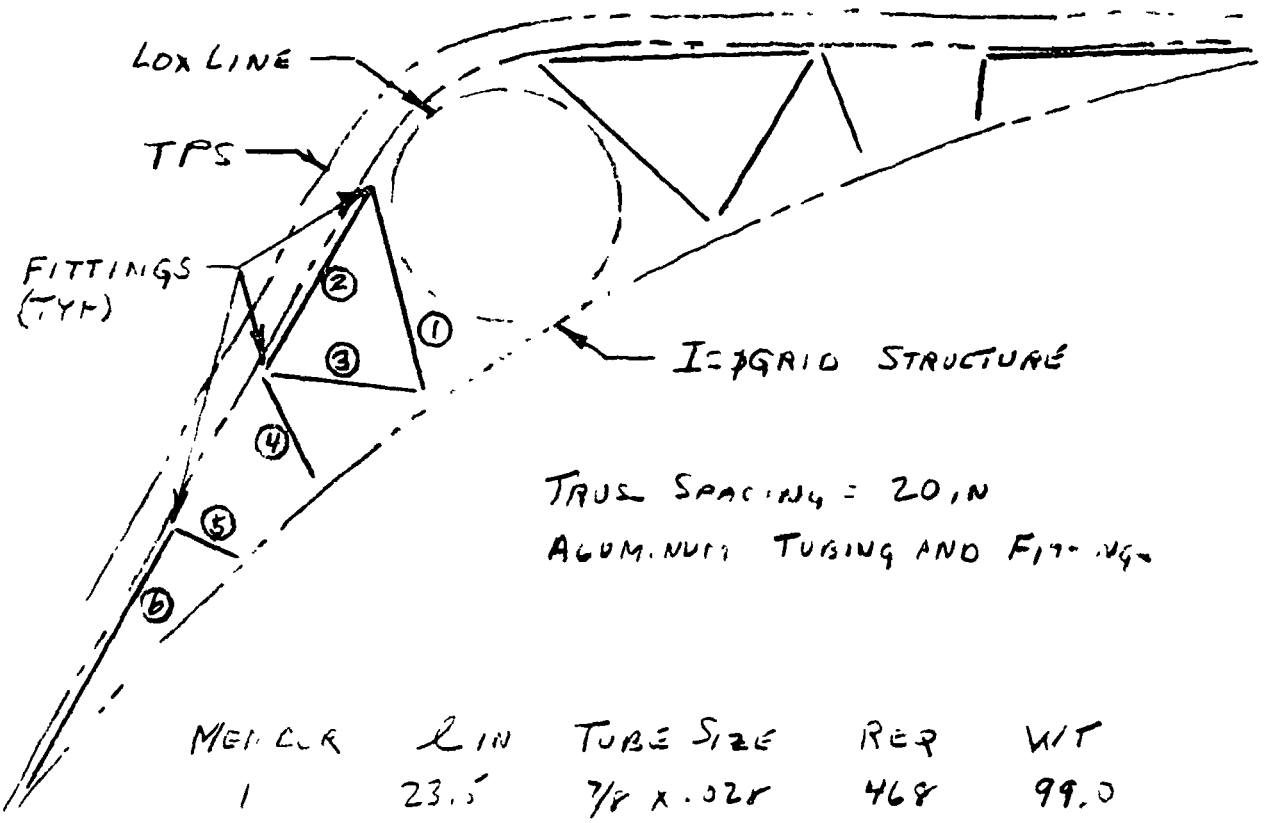
E–E
SCALE 1/1
TYPICAL ATTACHMENT TO ISOGRID



A–A
TYPICAL TPS ARRANGEMENT FOR BODY SHOULDER AREA

	BODY TPS INSTALLATION	
	CONFIGURATION 20.8	
94326	899A2010643	
13	SHEET 2 OF 2	

TPS STAND OFF
BODY SHOULDER AREA



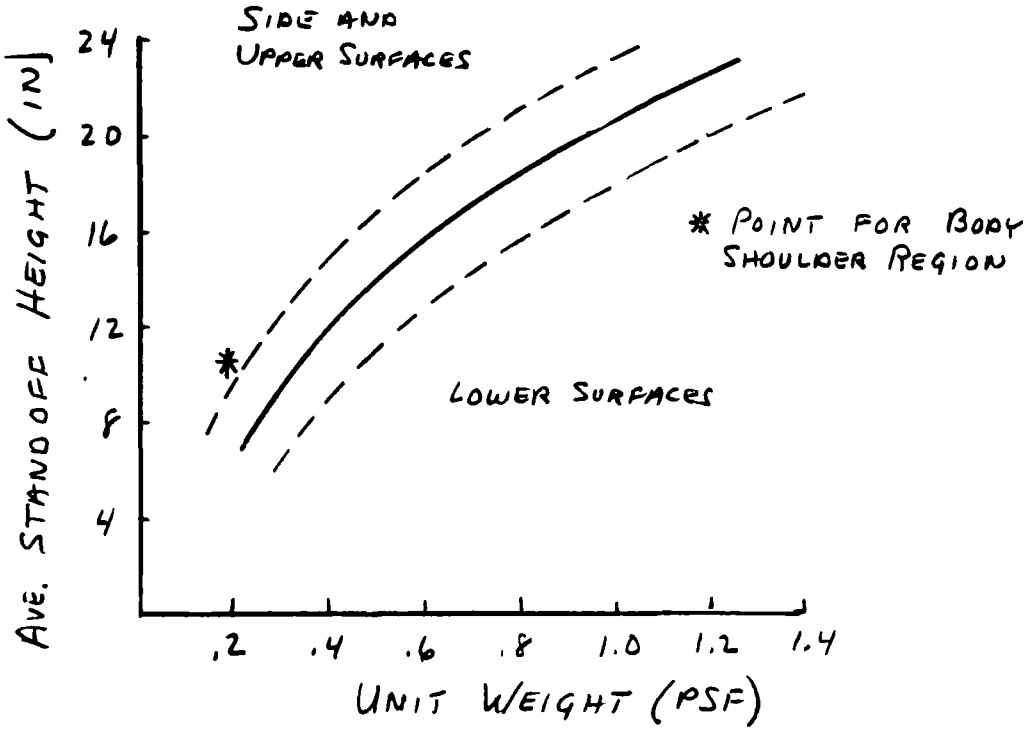
TRUSS SPACING = 20 IN
ALUMINUM TUBING AND FITTINGS

MEMBER	ℓ IN	TUBE SIZE	PER	WT
1	23.5	7/8 x .028	468	99.0
2	25.0	3/4 x .028	468	53.8
3	21.5	7/8 x .028	468	71.8
4	14.0	5/8 x .028	468	30.0
5	6.0	3/4 x .028	468	9.6
6	15.5	1/2 x .028	468	18.2
DRAG BRACE	20.8	1/2 x .028	468	37.1
FITTINGS	.0275 EA		936	25.8
	.0225 EA		468	10.5
	.0180 EA		1872	37.6
FASTENERS	.006 + .004	x	650	65.5
CONTINGENCY	5%			23.0

479 LBS

TPS STAND OFF

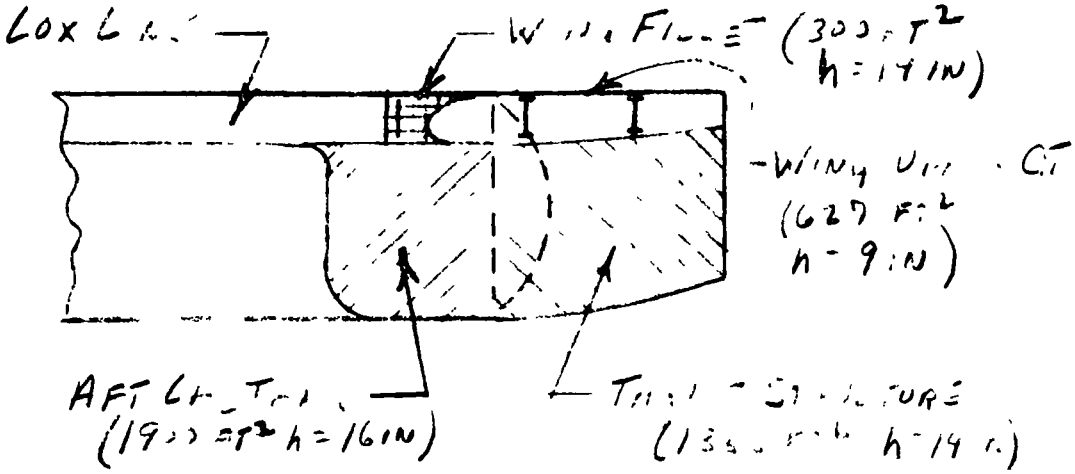
DUE TO THE VARYING HEIGHTS AND LOADS OF THE TPS STANDOFFS THE DESIGN CURVES BELOW WERE USED TO ASSESS THE WEIGHT PENALTY.

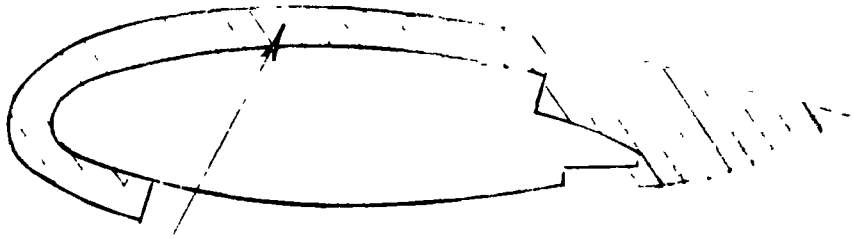


NOTE:
1) SUPPORTS FOR 26 IN. PANELS
2.) INCLUDES SIDE & DRAG BRACING

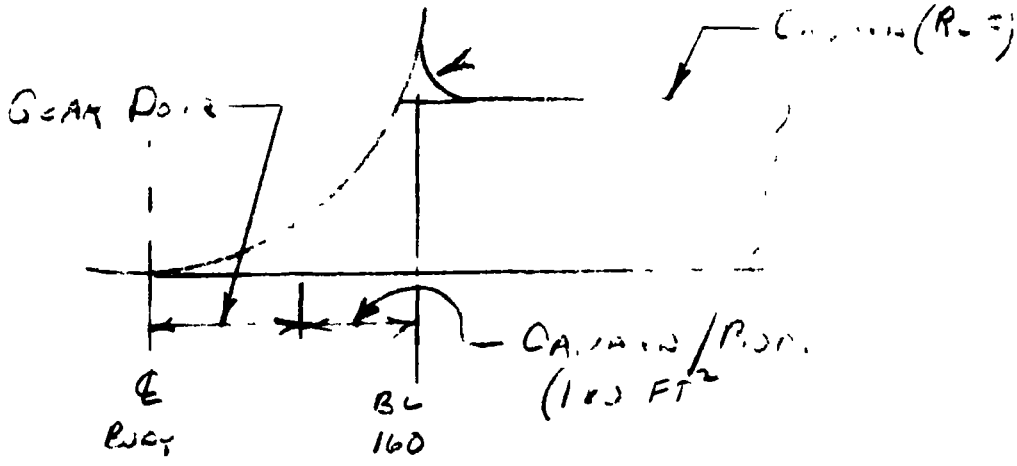
STAND OFF AREAS

(h = AVERAGE HEIGHT OF STAND OFF)





CANARD FAIRING AREA →
(202 FT²
h = 17 IN)



DETAIL WEIGHT SUMMARY

THERMAL PROTECTION SYSTEM

INSTRUMENTATION [263]

	No. Req	Unit Wt	Weight
PICKUPS	(300)		[69]
THERMO	180	.2	36
CALORIMETER	10	.5	5
PRESSURE	10	.3	3
STRAIN GAGE	50	.2	10
ACCELEROMETER	40	.3	12
MICROPHONE	10	.25	3
SUPTS 20%			[14]
WIRE 22 GAGE		.003 LB/FT	[180]

$\ell = \frac{300}{2}(240+160)$

$= 60{,}000$ FT

WT = 60 000 x .003 = 180 LB

5.0 LANDING AND ORBITER ATTACH [25885]

		WEIGHT (LB)	PAGE NO.
ALIGHTING GEAR	[22590]		2.5-4
MAIN GEAR	15060		2.5-27
ROLLING		(5760)	2.5-46
WHEELS		1456	2.5-46
TIRES		2096	2.5-46
BRAKES		2048	2.5-46
AIR		160	2.5-46
STRUCTURE		(8250)	2.5-28
CYLINDER		2290	2.5-28
PISTON		770	2.5-30
AXLE		640	2.5-32
SIDE BRACE		690	2.5-34
FIXED BRACE		250	2.5-36
TORQUE LINKS		390	2.5-38
ATTACH STRUCTURE		2840	2.5-40
INTERNAL PARTS		470	2.5-42
CONTROLS (SYSTEMS)		(1050)	2.5-44
NOSE GEAR	7530		2.5-9
ROLLING		(2880)	2.5-46
WHEELS		728	2.5-46
TIRES		1048	2.5-46
BRAKE		1024	2.5-46
AIR		80	2.5-46

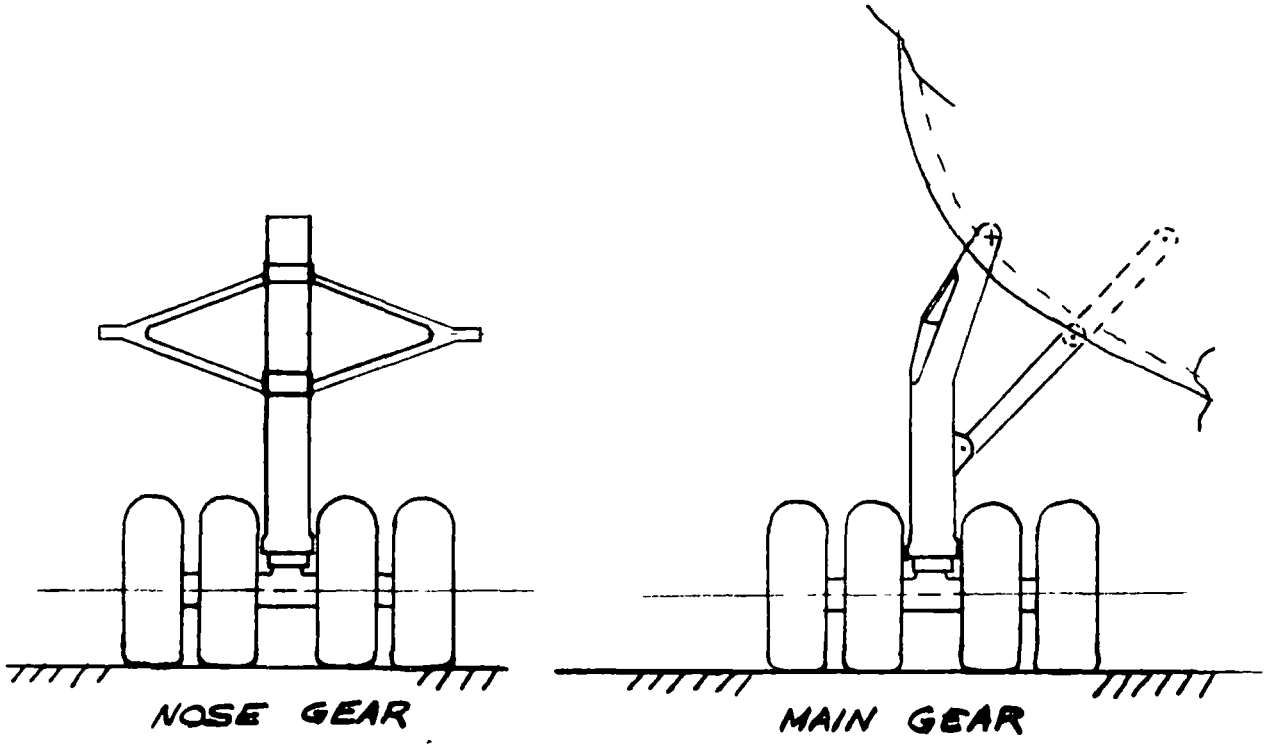
(CONTINUED)

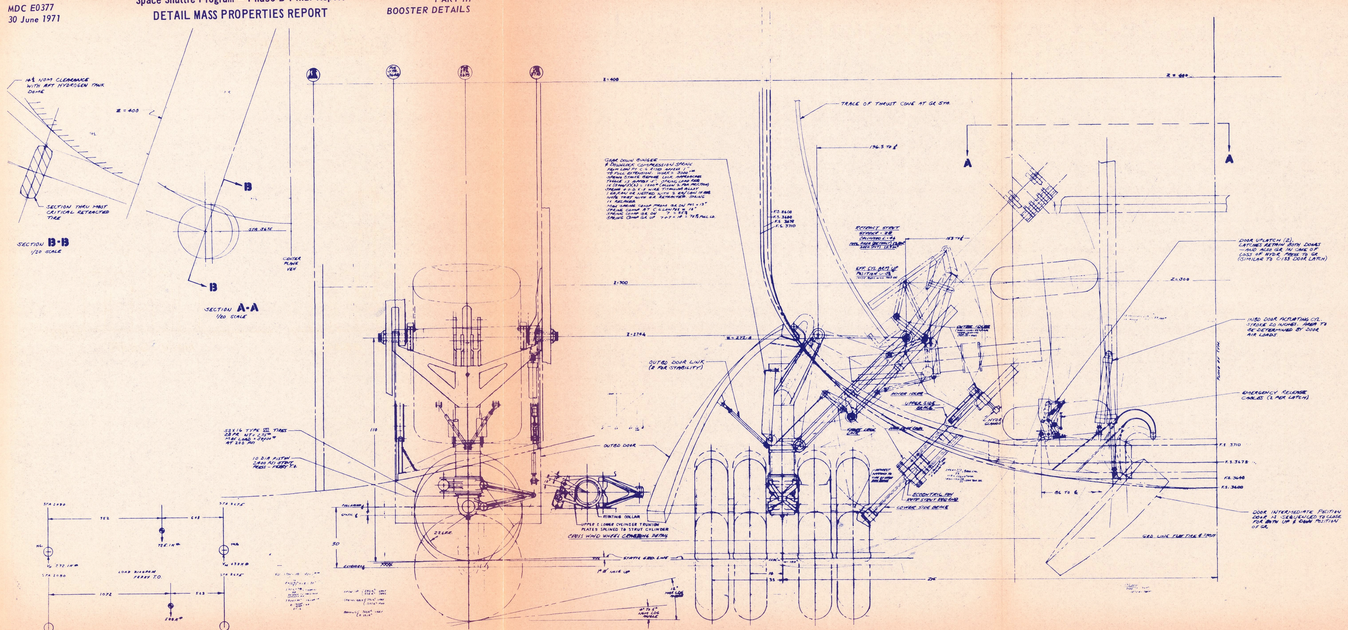
5.0 LANDING AND ORBITER ATTACH (CONTINUED)

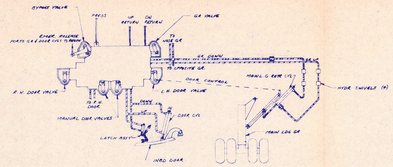
	WEIGHT (LB)	PAGE NO.
STRUCTURE	(4160)	2.5-10
CYLINDER	1000	2.5-10
PISTON	370	2.5-12
AXLE	370	2.5-14
DRAG LINK	420	2.5-16
TORQUE LINK	230	2.5-18
ATTACH STRUCTURE	620	2.5-20
INTERNAL PARTS	340	2.5-22
STEERING	810	2.5-26
CONTROLS (SYSTEMS)	(490)	2.5-24
ORBITER ATTACH [3295]		2.5-49
AFT ATTACH	(2320)	2.5-51
FORWARD ATTACH	(508)	2.5-64
SEPARATION MECHANISM	(310)	2.5-68
CONTINGENCY (5%)	(157)	

	ROLLING	STRUC-TURE	CON-TROLS	
5. LANDING, DOCKING				25985
ALIGHTING GEAR				22500
MAIN	5760	8250	1050	
NOSE	2880	4160	490	
DOCKING				
AUXILIARY SYSTEMS				3295
DECELERATION CHUTES			0	
FLOTATION GEAR			0	
ORBITER ATTACH			3295	
CONTINGENCY				0

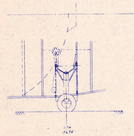
LANDING GEAR

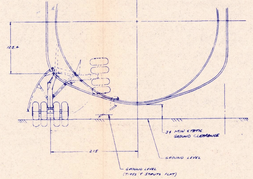






SCHEMATIC – MAIN GR EXTENSION & RETRACTION





GENERAL NOTES

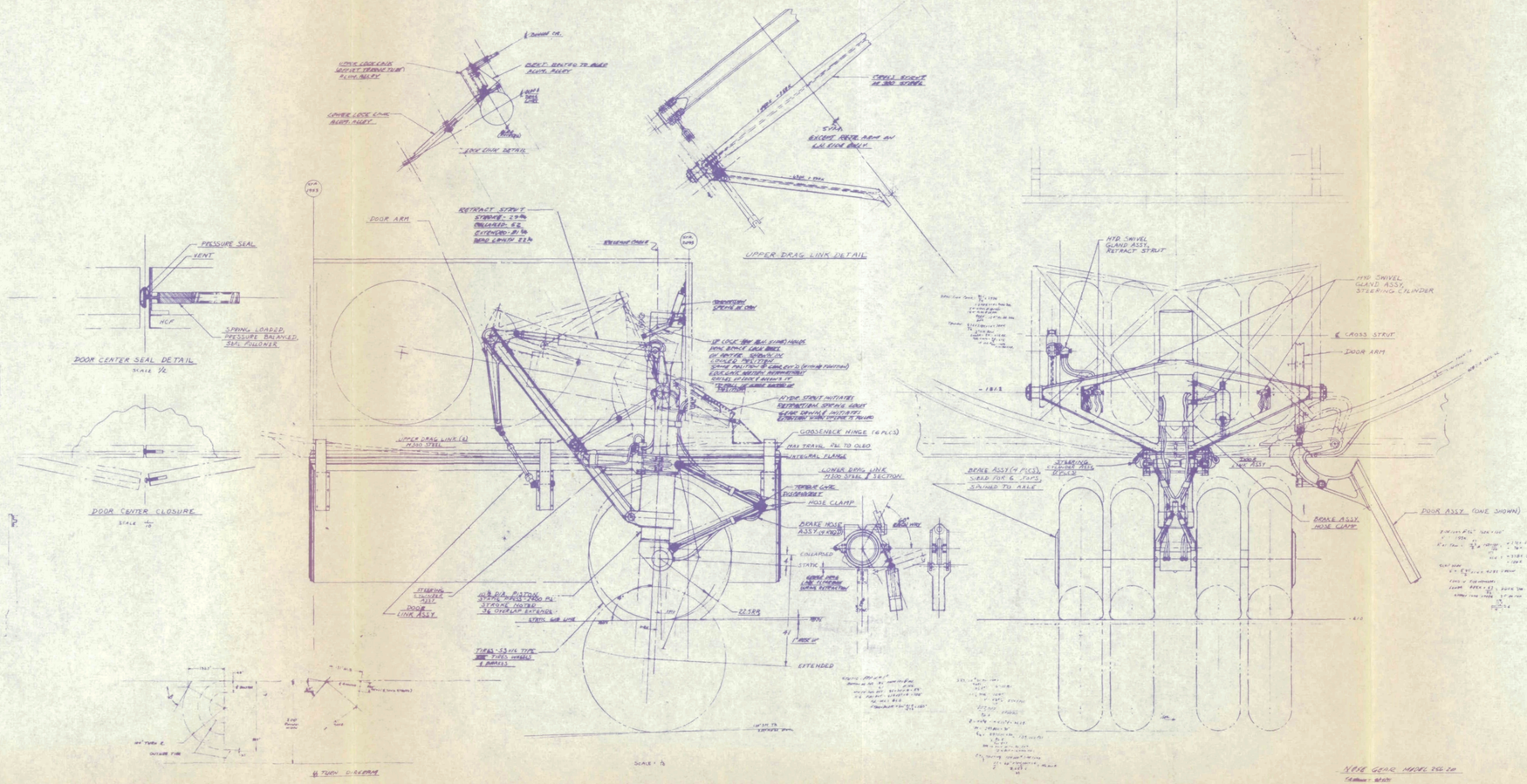
- FOR GEAR DESIGN LOADS SEE MDC E0375 PART III BOOSTER AIRFRAME

REVISIONS

LTR	DESCRIPTION	CHANGE	DATE
A	RECORD ISSUE		

LAYOUT-INSTALLATION, MAIN LANDING GEAR

256-20-0010



REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADDED DOORS, HYDRAULICS & SEALS	4/4/71	

LAYOUT-INSTALLATION, NOSE LANDING GEAR

J 18306 | 25C-20-0011

LANDING GEAR WEIGHT DERIVATION

The landing gear weight estimation is based on a series of graphic representations of gear components using rational design parameters developed by McDonnell Douglas. These design parameters take into account the vehicle's critical design conditions and the geometry of the gear components.

The tables beginning on page 2.5-6 show the data required for the use of the graphs and the data used for this study.

Subsequent to the parametric analysis a detailed calculated analysis was performed on the main gear in order to check the parametric approach. The detail calculations substantiated the parametric method by agreeing within 1.5 per cent.

MAIN LANDING GEAR WEIGHT COMPARISON
PARAMETRIC DERIVATION VERSUS PRELIMINARY CALCULATED WEIGHT

DESCRIPTION	LBS / VEHICLE PARAMETRIC DERIVATION	CALCULATED WEIGHT
CYLINDER	3200.	3200.
PISTON	770.	990.
INTERNAL PARTS	470.	366.
TORQUE LINKS & PINS	390.	419.
AXLE, AXLE NUT & MISC ATTACH	640.	696.
LOWER & UPPER SIDE BRACE & ATTACH	690.	762.
FIXED BRACE	250.	◇
TRUNNION PINS	⬡	205.
SYSTEMS	1050.	1050. X
ATTACH STRUCTURE	3840.	3840. X
ROLLING ASSY	5760.	5760. X
	15,060.	15,388.

⬡ INCLUDED IN ATTACH STRUCTURE WEIGHT
X USED SAME WEIGHT AS PARAMETRIC DERIVATION
◇ INCLUDED IN ATTACH STRUCTURE WEIGHT

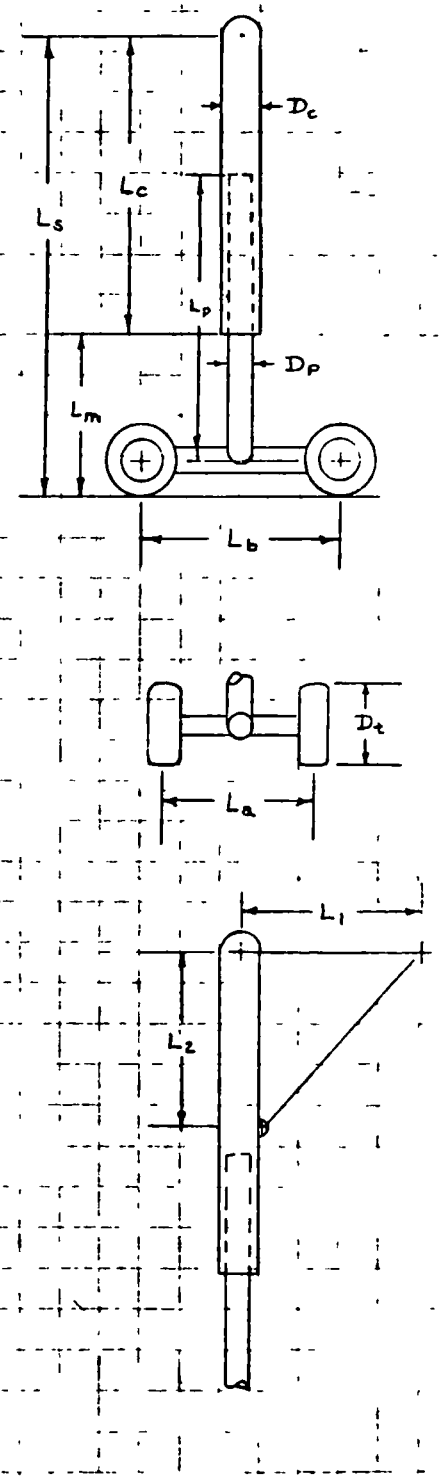
CONCLUSIONS:

THE ABOVE TABLE SHOWS THAT THE PARAMETRIC METHOD USED FOR THE MAIN GEAR DIFFERS FROM THE CALCULATED METHOD IN APPENDIX A (PAGE 3.0-1) BY LESS THAN 1.5%. IT IS EXPECTED THAT SIMILAR AGREEMENT COULD BE ACHEIVED FOR THE NOSE GEAR.

GEAR STUDY

DIMENSIONAL DATA REQUIRED

PISTON DIAMETER	D_p
CYLINDER DIAMETER	D_c
PISTON LENGTH	L_p
CYLINDER LENGTH	L_c
AXLE LENGTH	L_a
BOGIE LENGTH	L_b
STATIC HEIGHT	L_s
TIRE DIAMETER	D_t
PISTON MOMENT ARM	L_m
STROKE LENGTH	S
NO. OF STRUTS	
NO. OF BOGIE BEAMS	
NO. OF AXLES	
NO. OF TIRES	
MTOGW	M (LBS)
MLW	LBS
FIXED BRACE GEOMETERY 1	L_1
SIDE BRACE GEOMETERY 2	L_2



LANDING GEAR DIMENSIONAL DATA

ITEM	SYMBOL	SHUTTLE ** MAIN	SHUTTLE ** NOSE	DC 10-30 MAIN	DC8-63 MAIN	DC9-30 MAIN	DC10-30 CENTERLINE MAIN
PISTON DIA.	D_p	10.0	10.5	11.5	9.5	5 25	7.8
CYLINDER DIA	D_c	12.0	12.5	13.5	10.3	5.8	9.5
PISTON LENGTH	L_p	38.8	61 0	69.7	48.9	37 2	67 0
CYLINDER LENGTH	L_c	78.0	80.0	91 0	62.7	42.2	59 0
AXLE LENGTH	L_a	51 0	51.0	54.0	30.0	24 0	37.5
BOGIE LENGTH	L_b	0	0	64.0	55.0	0	0
STATIC HEIGHT	L_s	110.0	85 0	135.0	93.5	65.6	96 0
TIRE DIA.	D_t	53.0	53.0	50 0	44.0	40.0	50.0
PISTON MOM ARM	L_M	32.0	35.0	44.0	30.8	23.4	43 0
STROKE LENGTH	S	30 0	41 0	23.5	16.0	15 0	23.5
FIXED BRACE LTH.	L_1	62 0	0	89.5	62 2	38.5	0
SIDE BRACE LTH	L_2	55.0	0	50.0	36.0	31.5	0
NO. OF STRUCTS		2	1	2	2	2	1
NO OF BOGIE BEAM		0	0	2	2	0	0
NO OF AXLES		2	1	4	4	2	1
NO. OF TIRES		8	4	8	8	4	2
MTOW	W	725 K	*292 K	555 K	355 K	109 K	*95 K
DRAG LINK L_1	L_1		62				
DRAG LINK L_2	L_2		62				

* EFFECTIVE MTOW USED IN CALCULATION

** ESTIMATED

LANDING GEAR WEIGHT SUMMARY

MAIN LANDING GEAR

	Wt	
CYLINDER	2200.	
PISTON	770.	
AXLE	640.	
SIDE BRACE	690.	
FIXED BRACE	250	
TORQUE LINKS	390.	
ATTACH STRUCTURE	2840.	
INTERNAL PARTS	470.	
SYSTEMS	1050.	
	9300.	
ROLLING ASSY	5760	
TOTAL MAIN GEAR	15,060.	lbs

NOSE LANDING GEAR

CYLINDER	1000	
PISTON	370	
AXLE	370	
DRAG LINK	420.	
TORQUE LINK	230	
ATTACH STRUCTURE	620.	
INTERNAL PARTS	340.	
SYSTEMS	490	
STEERING	810	
	4650.	
ROLLING ASSY	2880.	
TOTAL NOSE GEAR	7530	lbs

TOTAL LANDING GEAR 22,590. lbs

NOSE LANDING GEAR WEIGHT DERIVATION

The nose landing gear weight estimation is based on a series of graphic representations of gear components using rational design parameters developed by McDonnell Douglas. These design parameters take into account the Vehicles critical design conditions and the geometry of the gear components.

The maximum take off weight (MTOW) of the booster will cause maximum static nose gear load of 292000. lbs. This static load is identical to the maximum vertical load referenced in the Shuttle Primary Loads, MEMO SSPI-E450-576 sect 4.1.1.5, without any load factor. Therefore 292×10^3 lbs was used as the "effective MTOW" for calculating NOSE gear weights The use of the maximum vertical static load as the "effective MTOW" is identical to the method use for the DC10-30 center line main landing gear analysis.

NOSE LANDING GEAR - CYLINDER

$n = 292\ K \qquad L_s = 85$

$L_c = 80 \qquad N = 1$

$$\theta = N^{1/3} (W \times L_s)^{2/3} L_c \times 10^{-6}$$

$$= 1 (292 \times 10^3 \times 85)^{2/3} 80 \times 10^{-6}$$

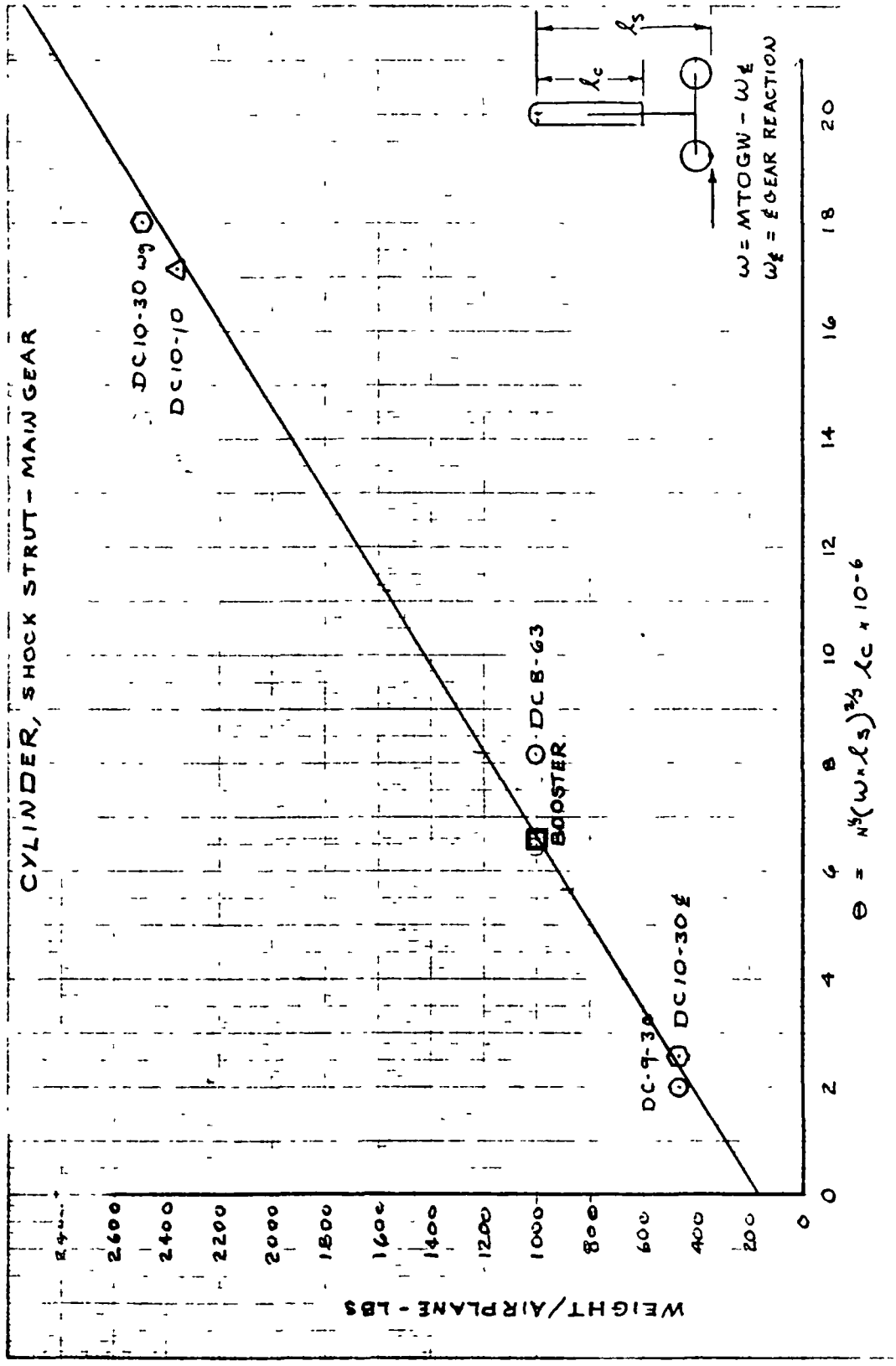
$$= (23{,}200 \times 10^6)^{2/3} \times 80 \times 10^{-6}$$

$$= 8.2 \times 10^4 \times 80 \times 10^{-6}$$

$\theta = 6.6$

From graph

$W_t =$ 1000 lbs / Vehicle


CYLINDER, SHOCK STRUT - MAIN GEAR
WEIGHT/AIRPLANE - LBS
DC10-30 wg
DC10-10
DC8-63
BOOSTER
DC-9-30
DC10-30ℓ
ℓ_s
ℓ_c
W = MTOGW - W_ℓ
W_ℓ = ℓ GEAR REACTION
$\Theta = N^{4/3}(W \times \ell_s)^{2/3} \ell_c \times 10^{-6}$

NOSE LANDING GEAR - PISTON

W = 292k L_P = 61

L_M = 35

$$\Theta = (W \times L_M)^{2/3} L_P \times 10^{-6}$$

$$= (292 \times 10^3 \times 35)^{2/3} 61 \times 10^{-6}$$

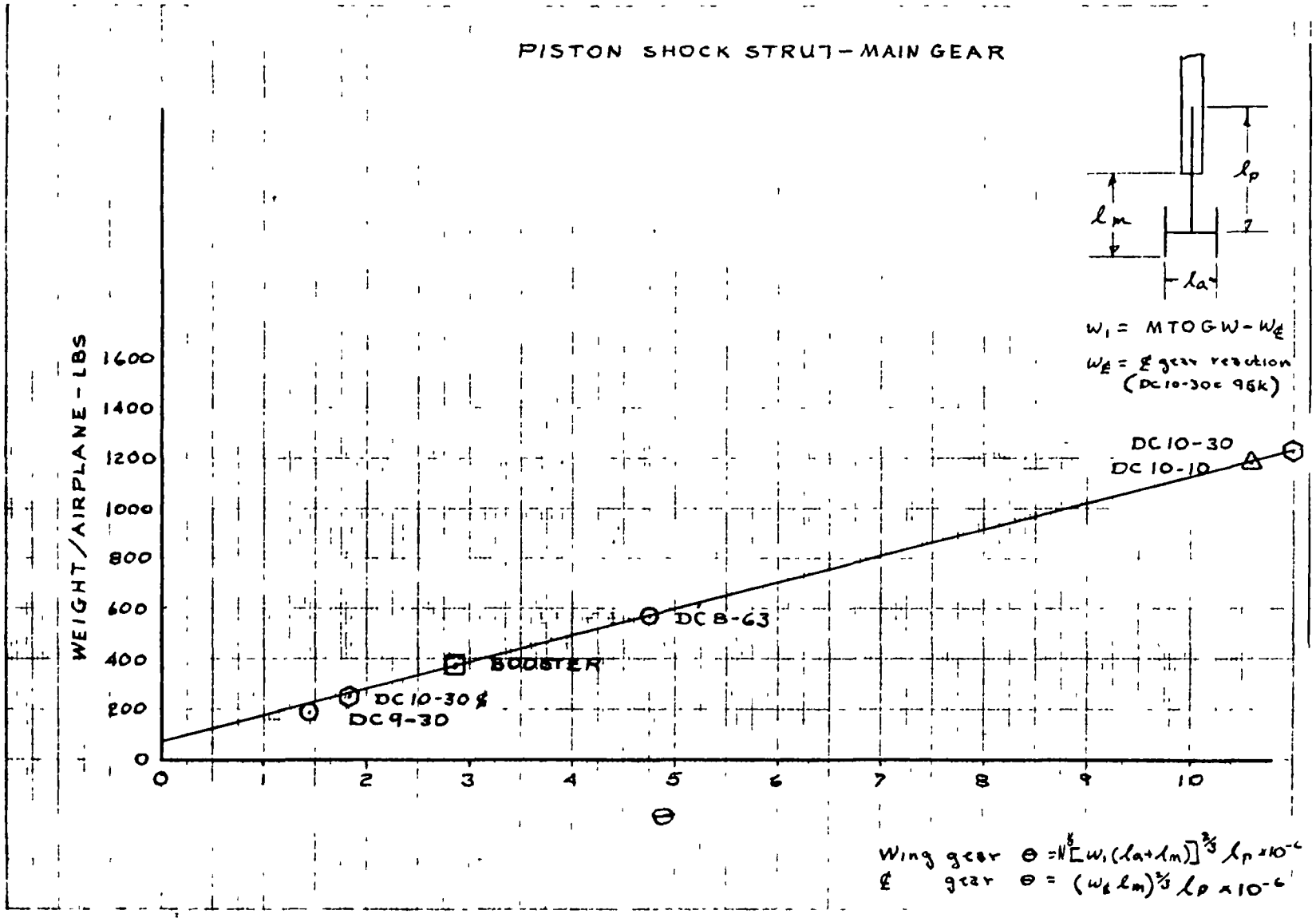
$$= (10{,}200 \times 10^3)^{2/3} 61 \times 10^{-6}$$

$$= 47 \times 10^4 \times 61 \times 10^{-6}$$

Θ = 2.87

from graph

Wt = 370 lbs / Vehicle


PISTON SHOCK STRUT – MAIN GEAR
WEIGHT/AIRPLANE – LBS
0
200
400
600
800
1000
1200
1400
1600
0
1
2
3
4
5
6
7
8
9
10
Θ
DC 10-30
DC 10-10
DC 8-63
BOOSTER
DC 10-30 ℄
DC 9-30
l_p
l_m
l_a
W_1 = MTOGW – $W_{℄}$
$W_{℄}$ = ℄ gear reaction
(DC 10-30 = 95k)
Wing gear $\Theta = N^{1/3}[W_1(l_a+l_m)]^{2/3}\, l_p \times 10^{-6}$
℄ gear $\Theta = (W_{℄}\, l_m)^{2/3}\, l_p \times 10^{-6}$

NOSE LANDING GEAR - AXLE

$W = 292\,K \qquad D_t = 53$

$L_a = 51 \qquad N = 1$

$$\theta = \left(\frac{W}{N}\right)^{2/3} \left(L_a + \frac{D_t}{2}\right)^{2/3} L_a \times N \times 10^{-4}$$

$$= (292 \times 10^3)^{2/3} (77.5)^{2/3} \times 51 \times 10^{-4}$$

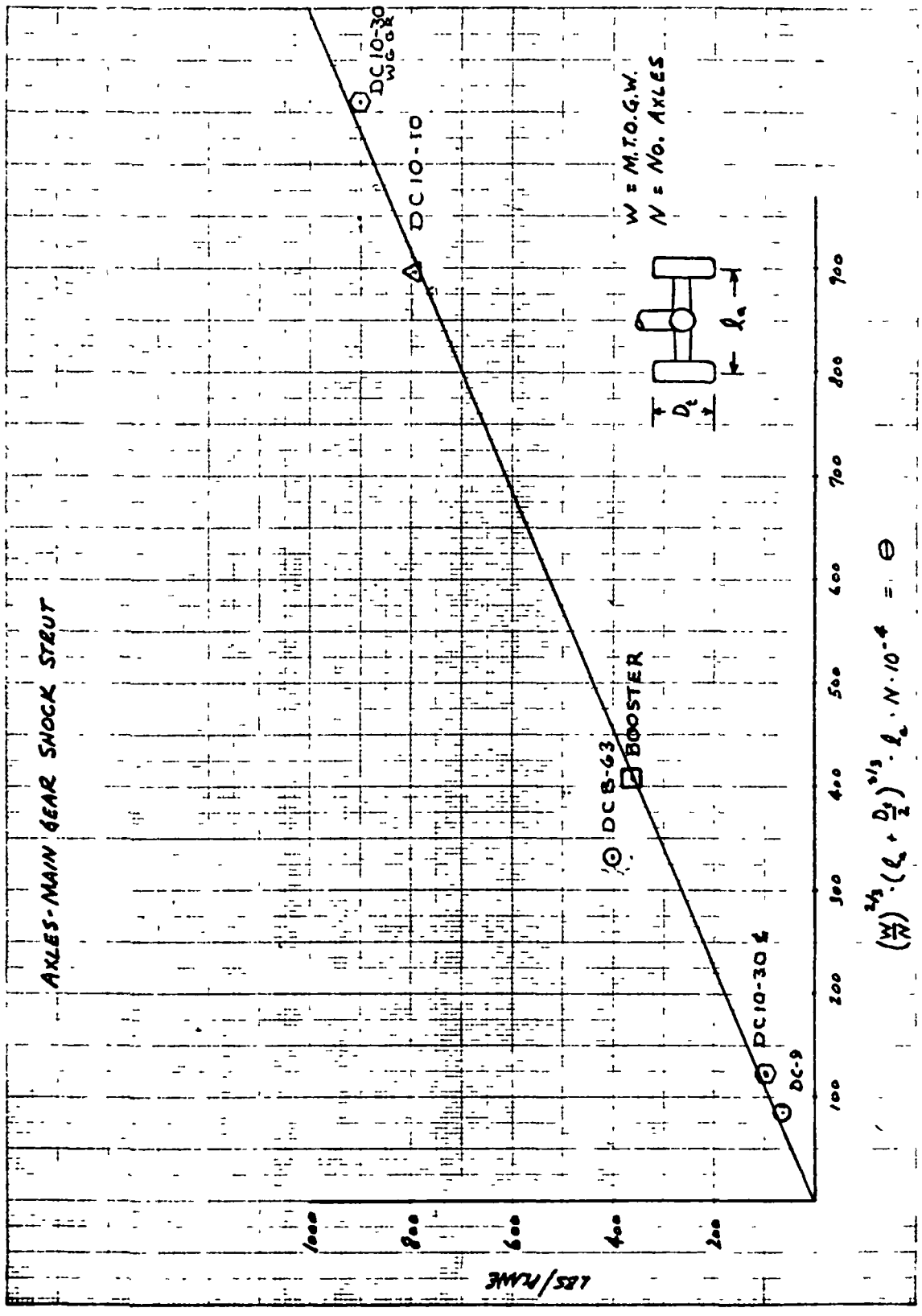
$$= 43.8 \times 10^2 \times 18.2 \times 51 \times 10^{-4}$$

$$\theta = 406$$

from graph

$Wt = \underline{370}$ lbs / vehicle

DATE _____
TITLE _____ REPORT BY _____



NOSE LANDING GEAR - DRAG LINK *

$W = 292\ K$

$L_1 \& L_2 = 62$

$$\theta = \frac{W\left(L_1^2 + L_2^2\right)^{3/2}}{L_1} \times 10^{-7}$$

$$= 292 \times 10^3 \frac{\left(62^2 + 62^2\right)^{3/2}}{62} \times 10^{-7}$$

$$= 292 \times 10^3 \times \frac{(7700)^{3/2}}{62} \times 10^{-7}$$

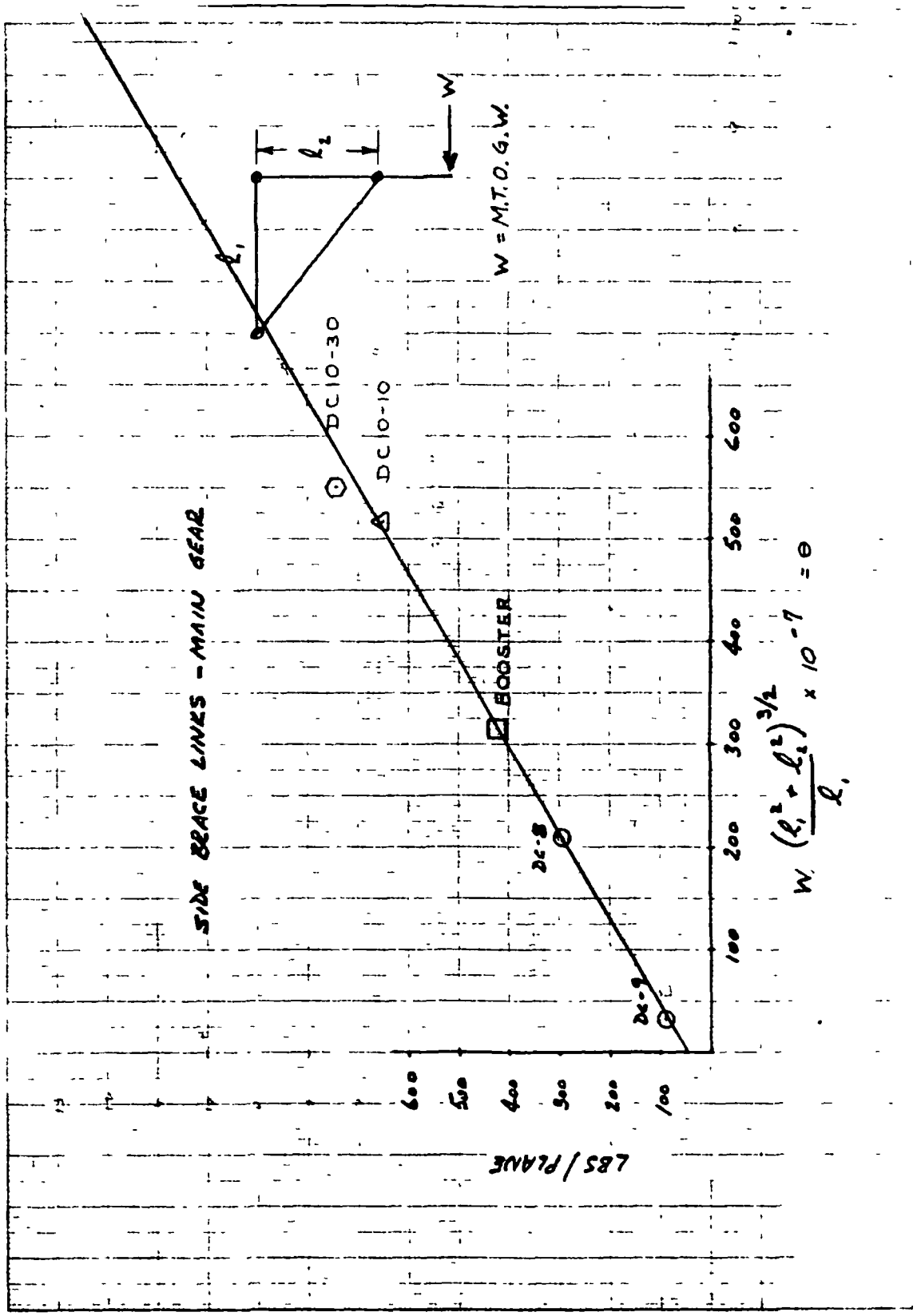
$$= 292 \times 10^3 \times 10.8 \times 10^3 \times 10^{-7}$$

$\theta = 315.$

From graph

Wt = 420 lbs / Vehicle

* ASSUME SIDE BRACE calculations approximate DRAG BRACE WEIGHTS


W
l_2
l_1
W = M.T.O.G.W.
DC10-30
DC10-10
SIDE BRACE LINES - MAIN GEAR
BOOSTER
DC-8
DC-9
LBS / PLANE
600
500
400
300
200
100
$W\frac{(l_1^2+l_2^2)^{3/2}}{l_1} \times 10^{-7} = 0$

NOSE LANDING GEAR - TORQUE LINKS

$W = 292\,K \qquad L_b = 0$

$L_a = 51$

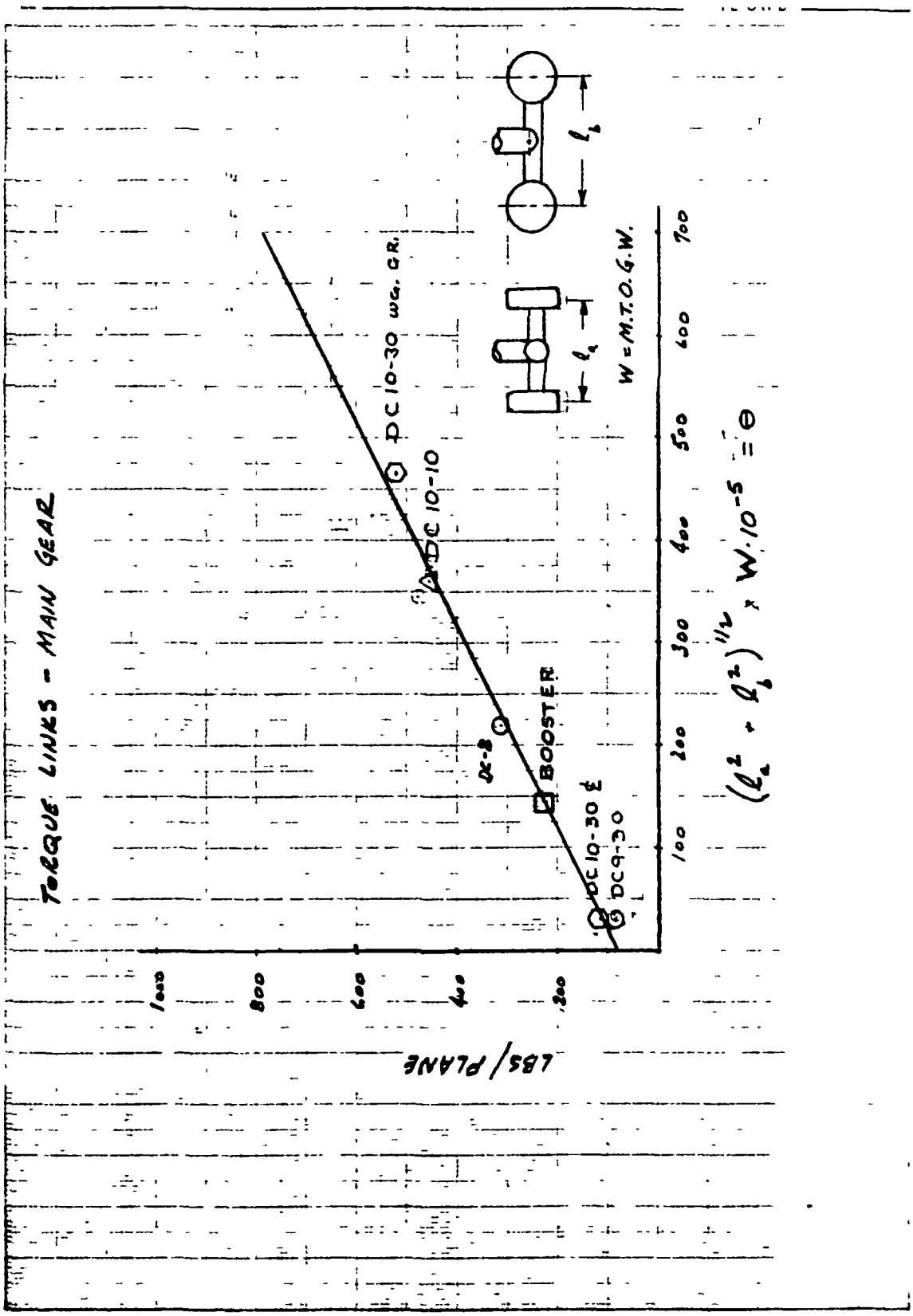
$\Theta = (L_a^2 + L_b^2)^{1/2} \times W \times 10^{-5}$

$= (51^2)^{1/2} \times 292 \times 10^{-5}$

$\Theta = 149$

from graph

$WT = \underline{\underline{230}}$ lbs / Vehicle


TORQUE LINKS - MAIN GEAR
DC 10-30 WG. GR.
DC 10-10
BOOSTER
DC 10-30 ℄
DC9-30
W = M.T.O.G.W.
LBS/PLANE
1000
800
600
400
200
100
200
300
400
500
600
700

NOSE LANDING GEAR - ATTACH STRUCTURE

$W = 292\,K$

$L_s = 85$

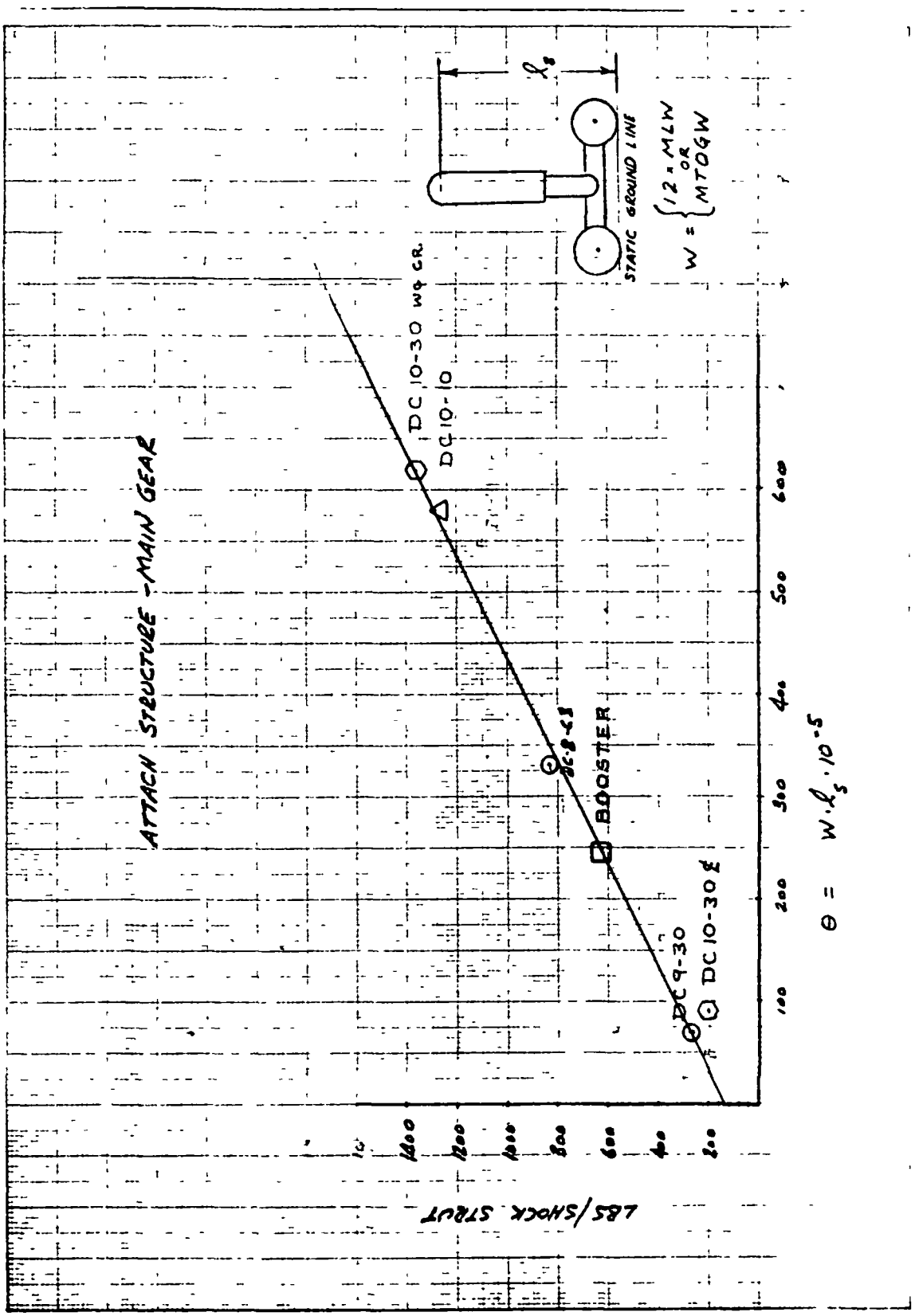
$\Theta = W \times L_s \times 10^{-5}$

$= 292 \times 10^3 \times 85 \times 10^{-5}$

$\Theta = 248$

from graph

Wt = 620 lbs /Vehicle


ℓ_s
STATIC GROUND LINE
W = { 1.2 × MLW OR MTOGW
DC 10-30 w/o CR.
DC 10-10
DC 9-30
DC 10-30
BOOSTER
ATTACH STRUCTURE - MAIN GEAR
LBS/SHOCK STRUT
$\Theta = W \cdot \ell_s \cdot 10^{-5}$
100
200
300
400
500
600
800
1000
1200
1400

NOSE LANDING GEAR- INTERNAL PARTS & FLUID

$S = 41 \qquad D_P = 10.5$

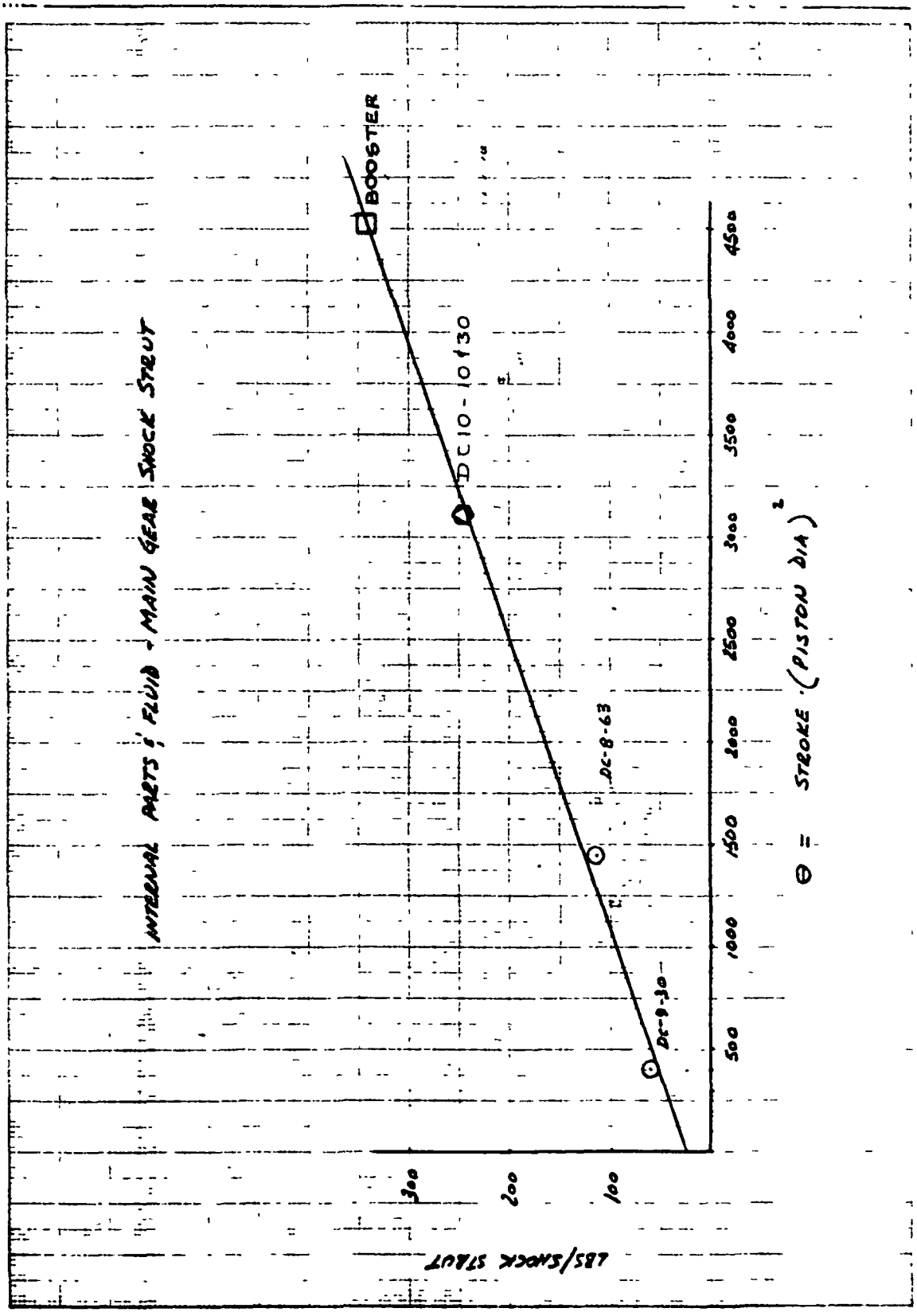
$\Theta = S(D_P)^2$

$= 41(10.5)^2$

$\Theta = 4520$

from graph

Wt = 340. lbs/Vehicle


BOOSTER
DC10-10130
DC-8-63
DC-9-30
INTERNAL PARTS & FLUID - MAIN GEAR SHOCK STRUT
Θ = STROKE · (PISTON DIA)²
185/SHOCK STRUT
300
200
100
500
1000
1500
2000
2500
3000
3500
4000
4500

NOSE LANDING GEAR - SYSTEMS *

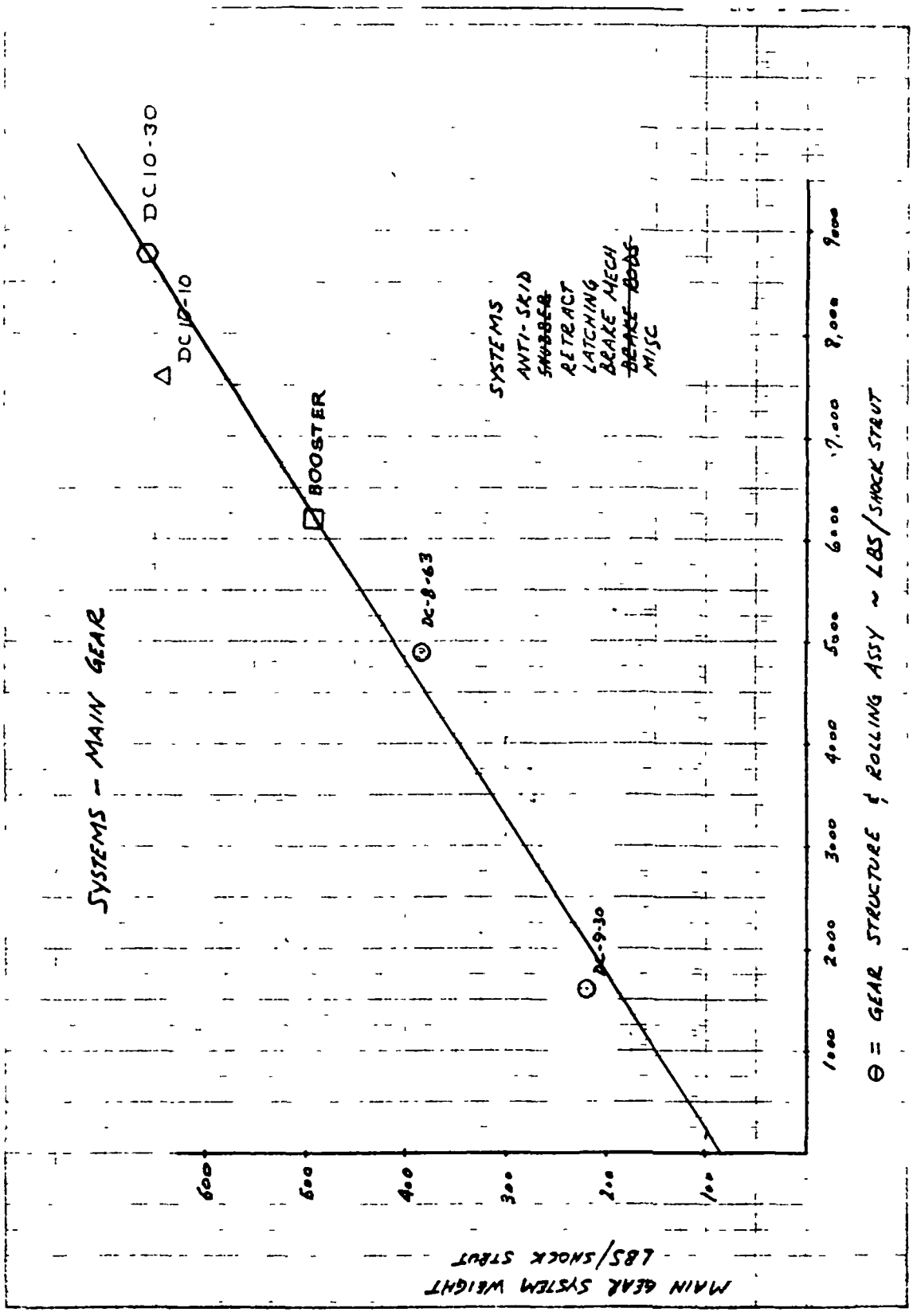
Rolling Assembly Wt	2880.
cylinder	1000.
piston	370.
AXLE	390.
DRAG LINK	420.
TORQUE LINK	230.
ATTACH STRUCT	620.
INTERNAL PARTS	340.
GEAR STRUCT & ROLLING ASSY	6210 lbs

From graph

Wt = 490 lbs / Vehicle

* SYSTEMS INCLUDE:

- ANTISKID
- RETRACT
- LATCHING
- BRAKE MECH.
- MISC


MAIN GEAR SYSTEM WEIGHT
LBS/SHOCK STRUT
600
500
400
300
200
100
SYSTEMS – MAIN GEAR
DC10-30
DC10-10
BOOSTER
DC-8-63
DC-9-30
SYSTEMS
ANTI-SKID
SHIMMER
RETRACT
LATCHING
BRAKE MECH
BRAKE BOOS
MISC
1000
2000
3000
4000
5000
6000
7,000
8,000
9000
Θ = GEAR STRUCTURE & ROLLING ASSY ~ LBS/SHOCK STRUT

NOSE LANDING GEAR - STEERING

DC 10-30 NOSE GEAR STEER. = $\frac{164}{1760}$ = 9.3% of total NOSE GEAR Wt

BOOSTER

NOSE GEAR Wt =	7530 lbs
	x.093
NOSE GEAR STEER =	700 lbs
+ Assume penalty	110 lbs
For high % of	810 lbs
MTOW on NOSE GEAR.	

MAIN LANDING GEAR WEIGHT DERIVATION

The main landing gear weight estimation is based on a series of graphic representations of gear components using rational design parameters developed by McDonnell Douglas. These design parameters take into account the vehicle's critical design conditions and the geometry of the gear components.

The MAXIMUM TAKE OFF WEIGHT (MTOW) of the booster was ratioed down to an "effective MTOW" for these weight estimations. The difference in the location of the vehicle C.G. with respect to main gear location, for the booster as compared to the DC10-30, indicates an "effective MTOW" of .817 MTOW.

THE EFFECTIVE MTOW IS DERIVED AS FOLLOWS:

BOOSTER	C G STA.
NOSE GEAR	2080.
MAIN GEAR	3675.
C.G.(FERRY MISSION) MAX. AFT	3280. *

∴ Main gear has $\frac{1200}{1590}$ or 75.3% MTOW as static load

DC10-30	
NOSE GEAR	578.
MAIN GEAR	1442.
CG.(Assume C/4)	1375.

∴ Main gear has $\frac{797}{864}$ or 92.2% of MTOW as static load

EFFECTIVE MTOW = $\frac{753}{922}$ = .817(725×10³) = <u>592×10³ lbs</u>

* MAX. AFT FERRY TAKE-OFF C.G. is derived by considering ALL FUEL carried in wing tanks.

MAIN LANDING GEAR - CYLINDER

$W = 592K \qquad N = 2$

$L_c = 78$

$L_s = 110$

$\Theta = N^{1/3} (W \times L_s)^{2/3} L_c \times 10^{-6}$

$= 1.26 (592 \times 10^3 \times 110)^{2/3} \times 78 \times 10^{-6}$

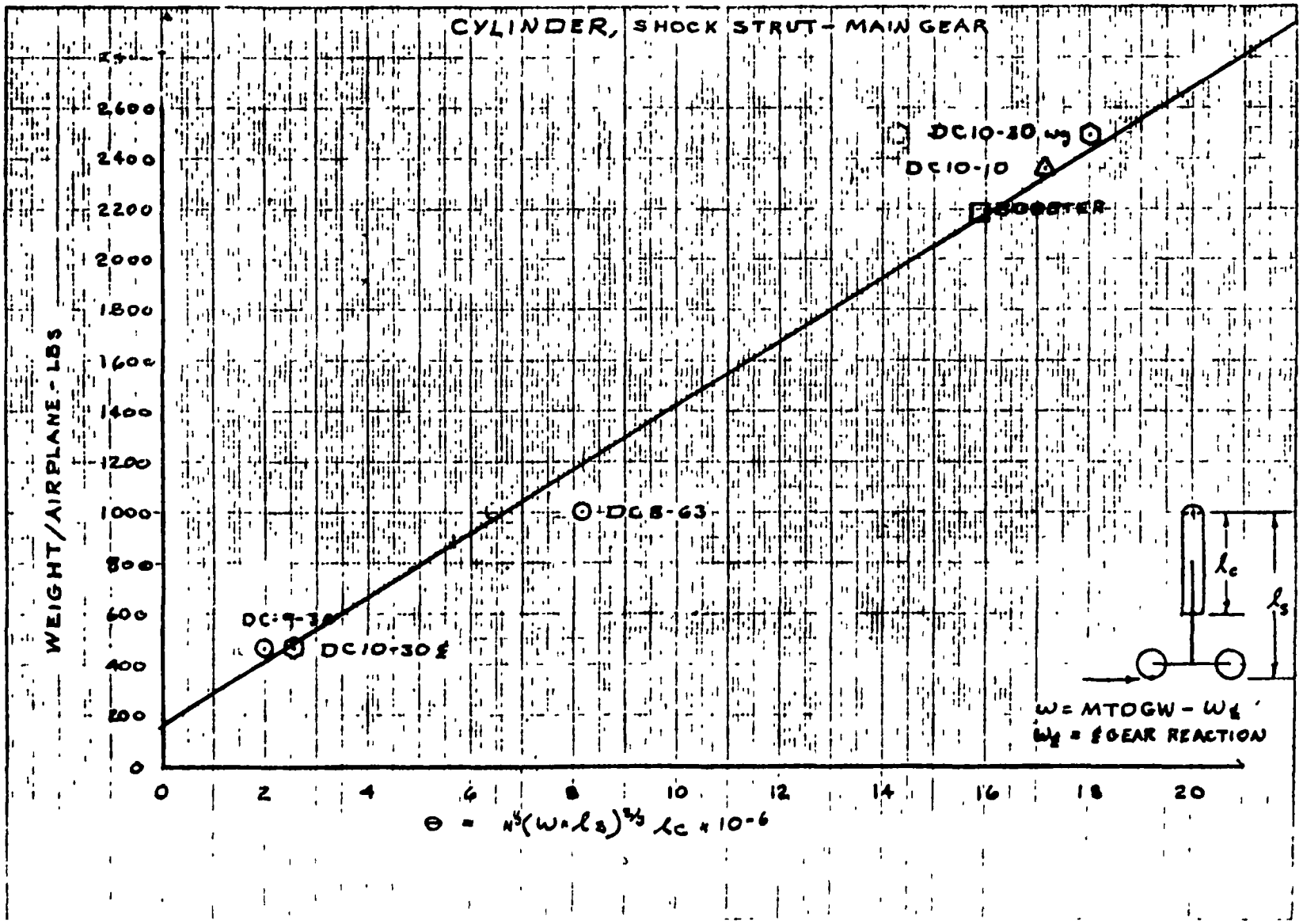
$= 1.26 (65{,}000 \times 10^6) \times 78 \times 10^{-6}$

$= 1.26 \times 16.1 \times 10^4 \times 78 \times 10^{-6}$

$\Theta = 15.8$

From graph -

Wt. = 2200 lbs / Vehicle


CYLINDER, SHOCK STRUT – MAIN GEAR
WEIGHT/AIRPLANE - LBS
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
16
18
20
DC10-30 wg
DC10-10
BOOSTER
DC8-63
DC10-30 ℄
ℓ_c
ℓ_s
ω = MTOGW – $\omega_{℄}$
$\omega_{℄}$ = ℄ GEAR REACTION
$\theta = N^{1/3}(\omega \times \ell_s)^{2/3}\ \ell_c \times 10^{-6}$

MAIN LANDING GEAR- PISTON

$W = 592\,K$ $\quad L_M = 32$

$L_p = 38.8$ $\quad L_a = 51$

$$\theta = N^{1/3}\left[W(L_a + L_m)\right]^{2/3} L_p \times 10^{-6}$$

$$= 1.26\left[592 \times 10^3 \times 83\right]^{2/3} \times 38.8 \times 10^{-6}$$

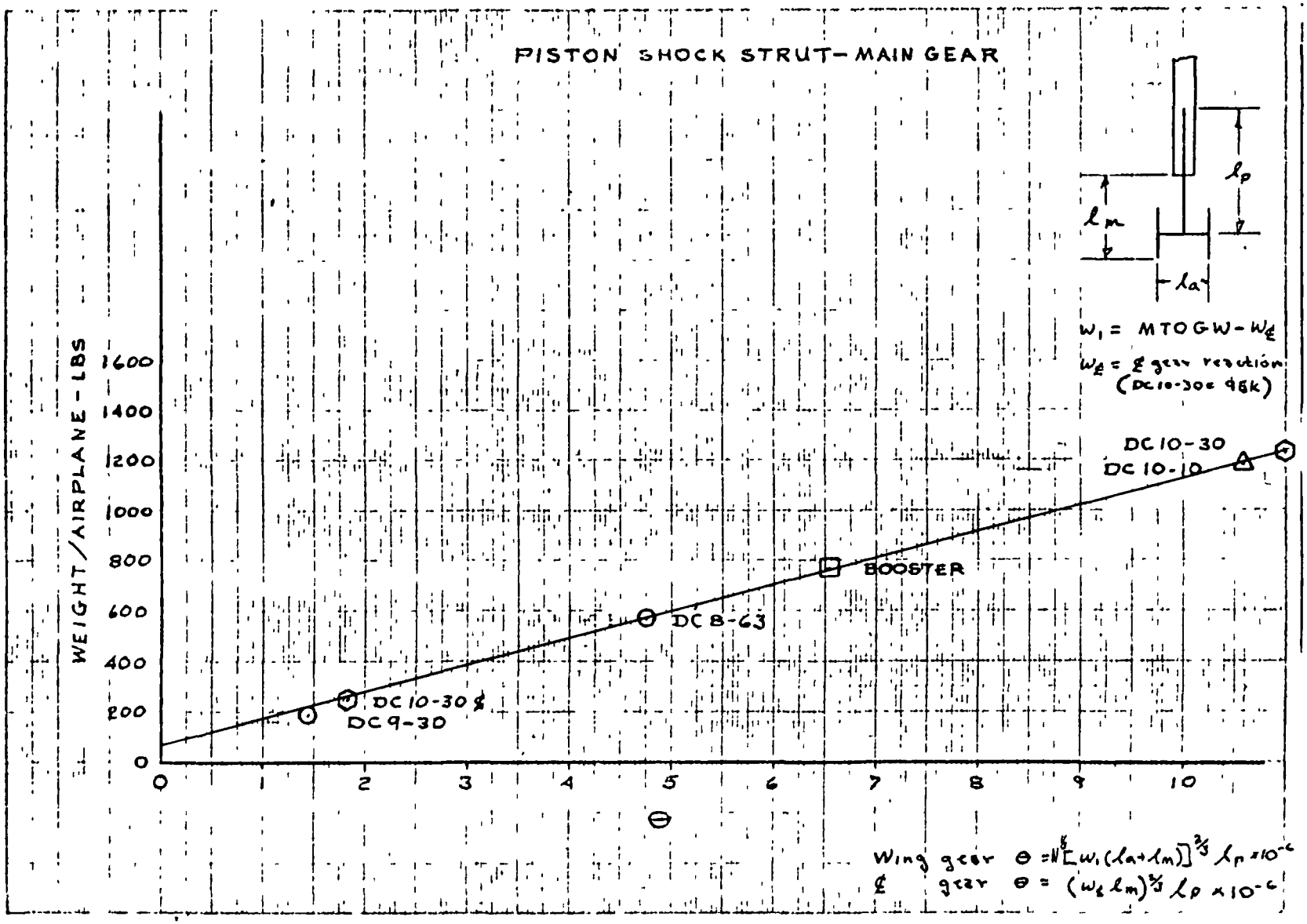
$$= 1.26\left[49100 \times 10^6\right]^{2/3} \times 38.8 \times 10^{-6}$$

$$= 1.26 \times 13.4 \times 10^{4} \times 38.8 \times 10^{-6}$$

$\theta = 6.55$

from graph:

$W_t = \underline{\underline{770}}$ lbs / vehicle


PISTON SHOCK STRUT–MAIN GEAR
WEIGHT/AIRPLANE – LBS
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
9
10
Θ
DC 10-30
DC 10-10
BOOSTER
DC 8-63
DC 10-30 ℄
DC 9-30
l_p
l_m
l_a
W_1 = MTOGW – $W_{℄}$
$W_{℄}$ = ℄ gear reaction
(DC10-30 = 95k)
Wing gear $\Theta = N^{1/3}[W_1(l_a+l_m)]^{2/3} l_p \times 10^{-6}$
℄ gear $\Theta = (W_{℄} l_m)^{2/3} l_p \times 10^{-6}$

MAIN LANDING GEAR - AXLE

$W = 592K$ $D_t = 53$

$L_a = 51$ $N = 2$

$$\Theta = \left(\frac{W}{N}\right)^{2/3}\left(L_a + \frac{D_t}{2}\right)^{2/3} L_a \times N \times 10^{-4}$$

$$= \left(\frac{592\times10^3}{2}\right)^{2/3}\left(77.5\right)^{2/3} 51 \times 2 \times 10^{-4}$$

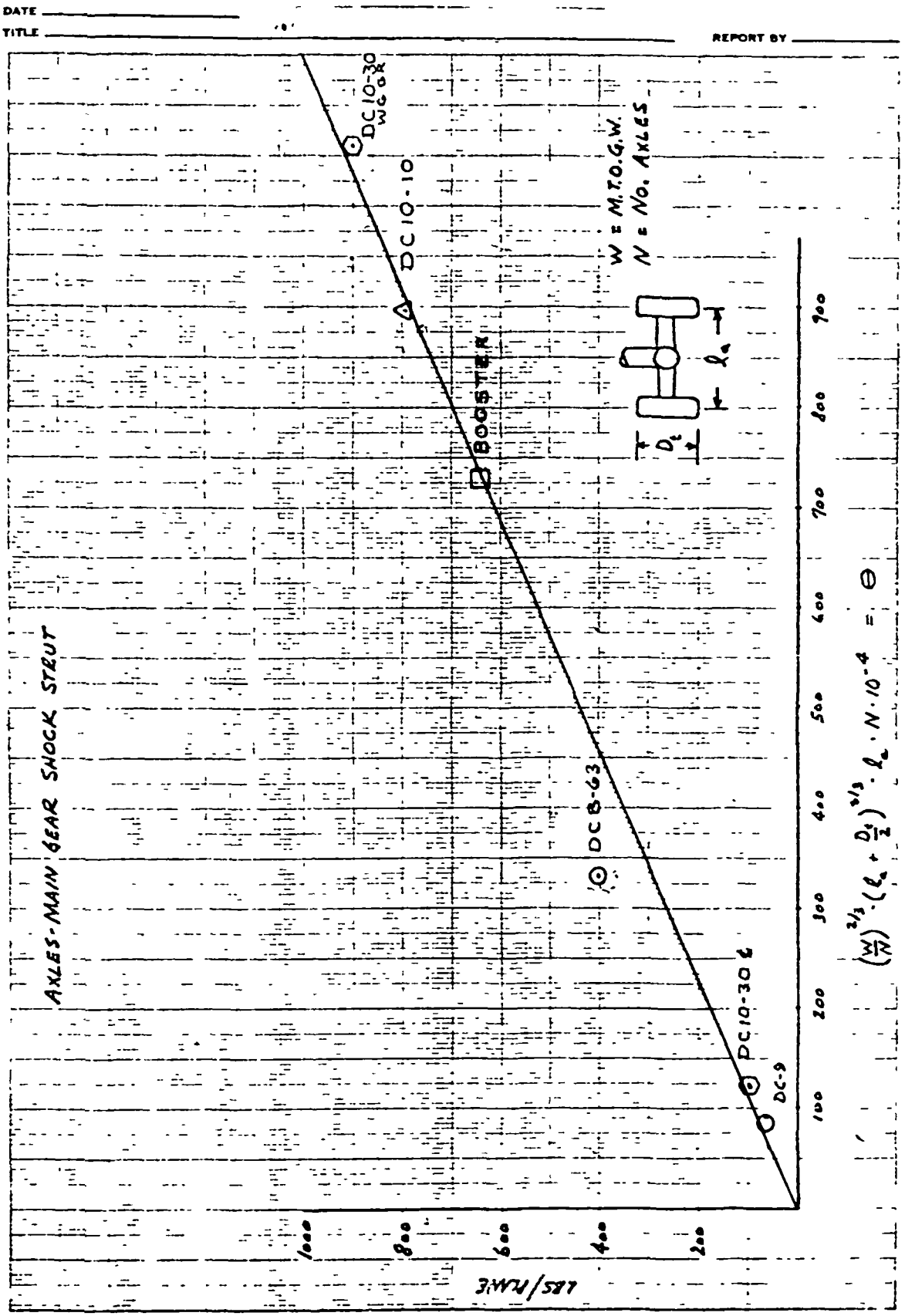
$$= 39.3\times10^2 \times 18.2 \times 51 \times 2 \times 10^{-4}$$

$\Theta = 730$

From graph -

Wt = 640 lbs / Vehicle

DATE _____
TITLE _____ REPORT BY _____



MAIN LANDING GEAR - SIDE BRACE

$W = 592\,K$

$L_1 = 62$

$L_2 = 55$

$$\theta = W \frac{\left(L_1^2 + L_2^2\right)^{3/2}}{L_1} \times 10^{-7}$$

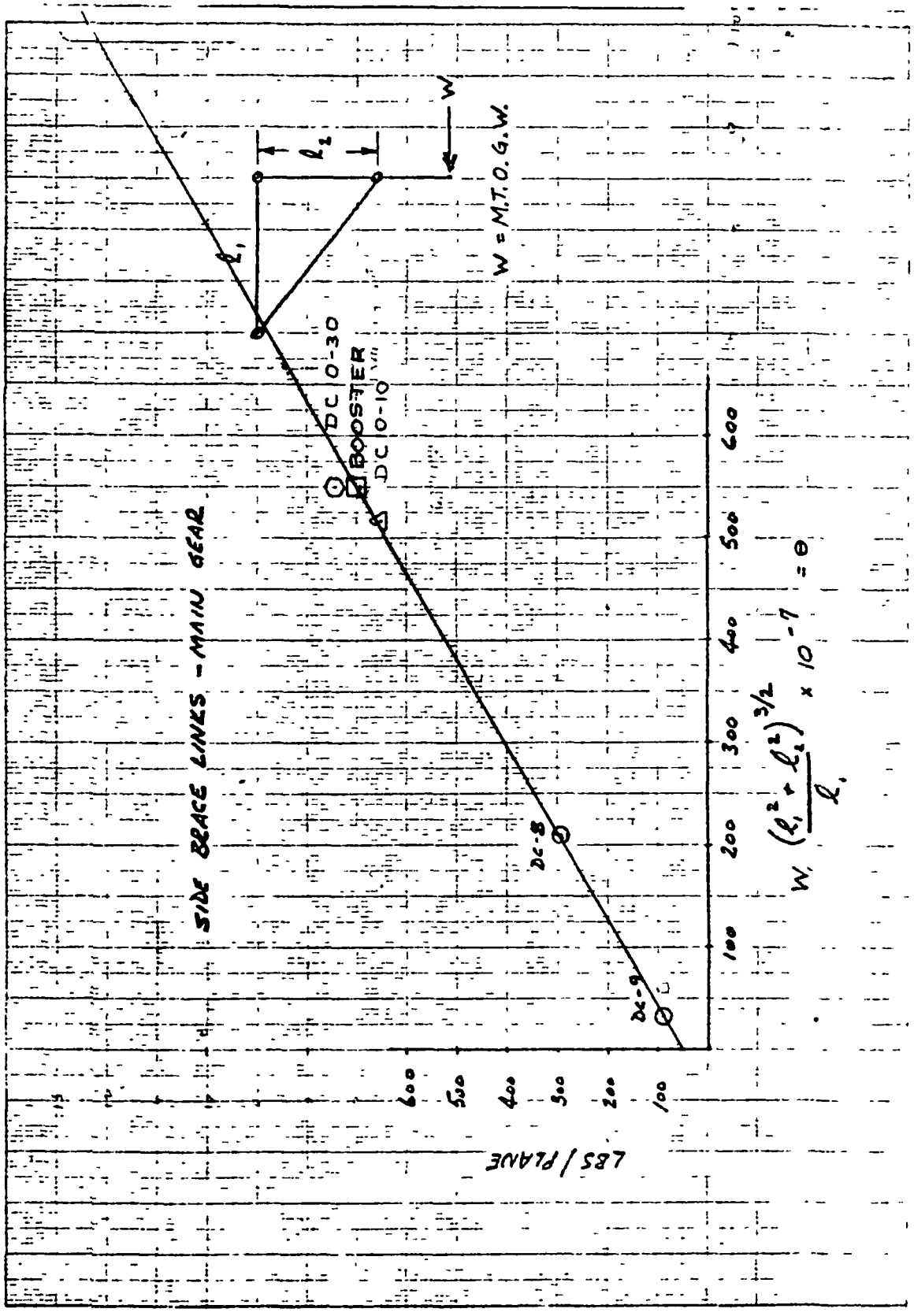
$$= 592 \times 10^3 \frac{(6862)^{3/2}}{62} \times 10^{-7}$$

$$= 592 \times 10^3 \times 9.12 \times 10^3 \times 10^{-7}$$

$\theta = 550$

..from graph -

$Wt = \underline{690}$ lbs / Vehicle


W
ℓ_2
ℓ_1
W = M.T.O.G.W.
DC 0-30
BOOSTER
DC 0-10
SIDE BRACE LINES - MAIN GEAR
DC-8
DC-9
LBS / PLANE
100
200
300
400
500
600
$W_i \frac{(\ell_1^2 + \ell_2^2)^{3/2}}{\ell_1} \times 10^{-7} = 0$

MAIN LANDING GEAR - FIXED BRACE

$W = 592 k$

$L_1 = 62$

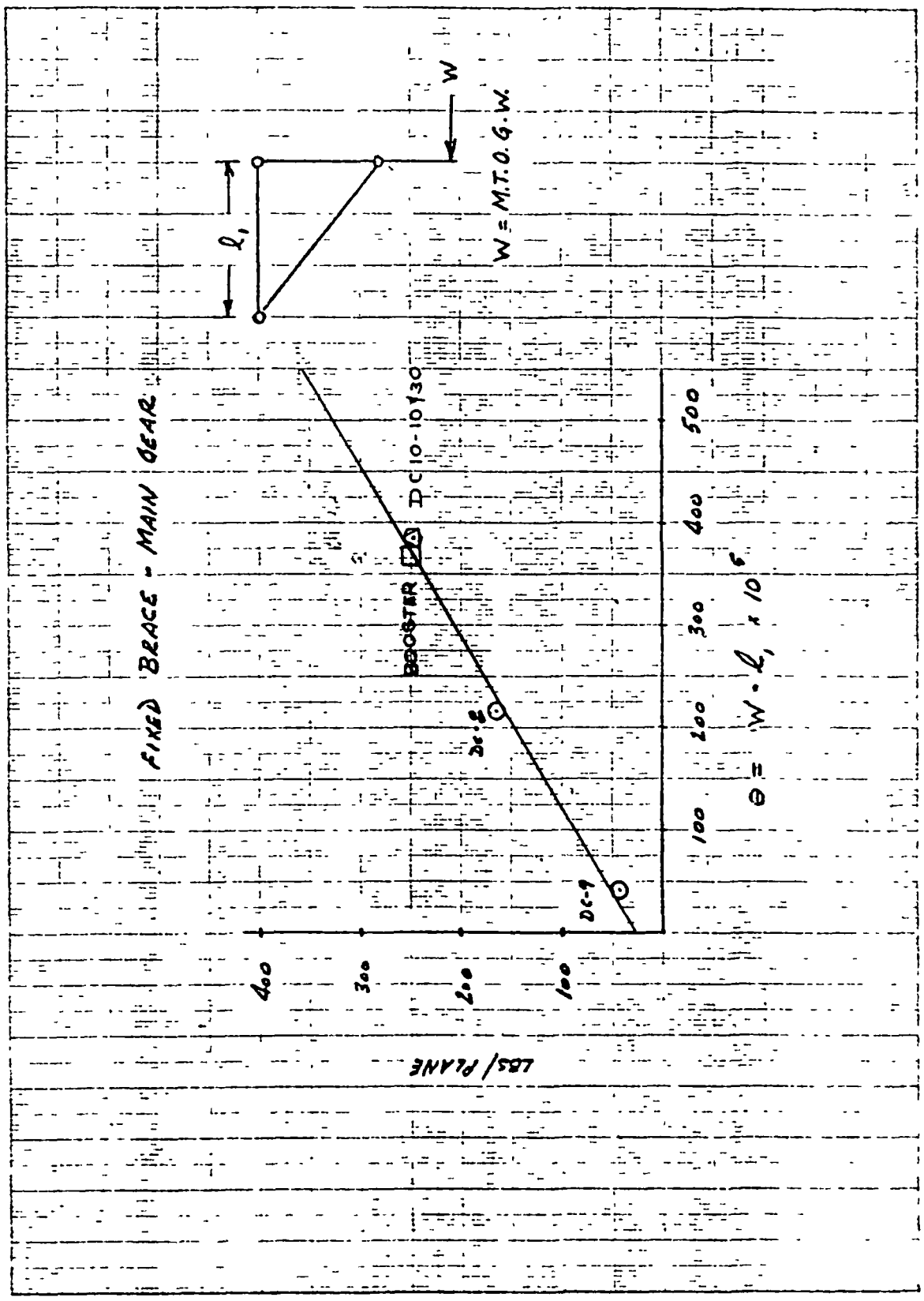
$\Theta = W \times L_1 \times 10^{-5}$

$\Theta = 592 \times 10^{3} \times .62 \times 10^{5}$

$\Theta = 367$

From graph

$Wt = \underline{250}$ lbs / Vehicle


W
W = M.T.O.G.W.
ℓ_1
FIXED BEACE - MAIN GEAR
DC10-10130
BOOSTER
DC-8
DC-9
500
400
300
200
100
$W \cdot \ell_1 \times 10^6$
400
300
200
100
LBS/ PLANE

MAIN LANDING GEAR - TORQUE LINKS

$L_a = 51$ $W = 592K$

$L_b = 0$

$\Theta = (L_a^2 + L_b^2)^{1/2} \times W \times 10^{-5}$

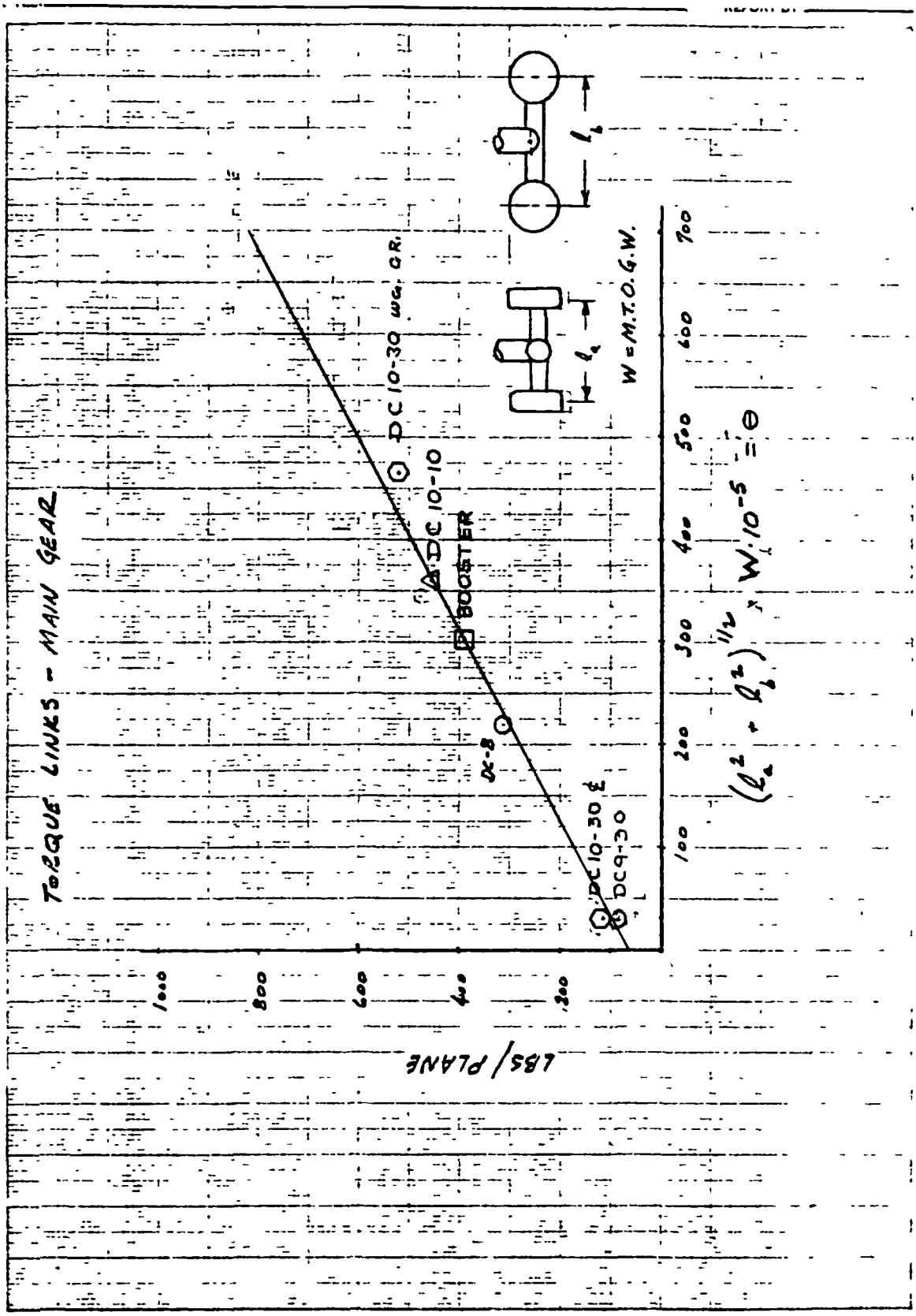
$= (51^2)^{1/2} \times 592 \times 10^3 \times 10^{-5}$

$= 51 \times 5.92 \times 10^3 \times 10^{-5}$

$\Theta = 302$

from graph

Wt = 390 lbs / vehicle


TORQUE LINKS - MAIN GEAR
LBS/PLANE
1000
800
600
400
200
100
200
300
400
500
600
700
W = M.T.O.G.W.
DC 10-30 wg. C.R.
DC 10-10
BOOSTER
DC-8
DC10-30 &
DC9-30
$(\ell_x^2 + \ell_y^2)^{1/2} \times W \times 10^{-5} = \Theta$

MAIN LANDING GEAR - ATTACH STRUCTURE

$W = 592K$

$L_S = 110$

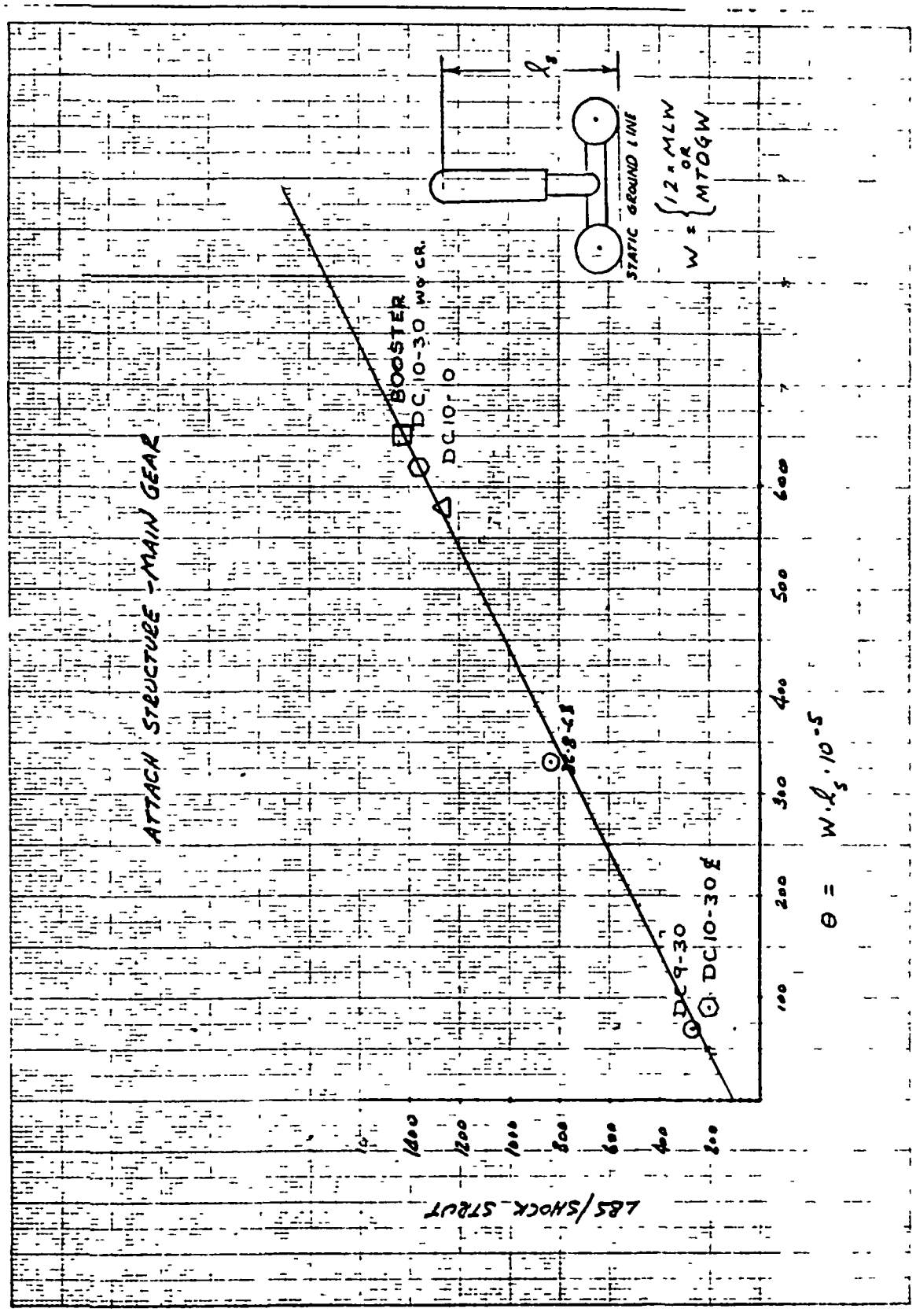
$\theta = W \times L_S \times 10^{-5}$

$= 592 \times 10^3 \times 110 \times 10^{-5}$

θ 652

from graph.

W_t = 1420 lbs/strut or 2840 lbs/vehicle


ℓ_s
STATIC GROUND LINE
W = { 1.2 x MLW OR MTOGW
BOOSTER
DC 10-30 W/ CR.
DC 10-10
DC 8-62
DC 9-30
DC10-30 F
ATTACH STRUCTURE - MAIN GEAR
LBS/SHOCK STRUT
$\theta = W \cdot \ell_s \cdot 10^{-5}$
1400
1200
1000
800
600
400
200
100
700
600
500
400
300
200
100

MAIN LANDING GEAR - INTERNAL PARTS & FLUID

$S = 30$

$D_p = 10$

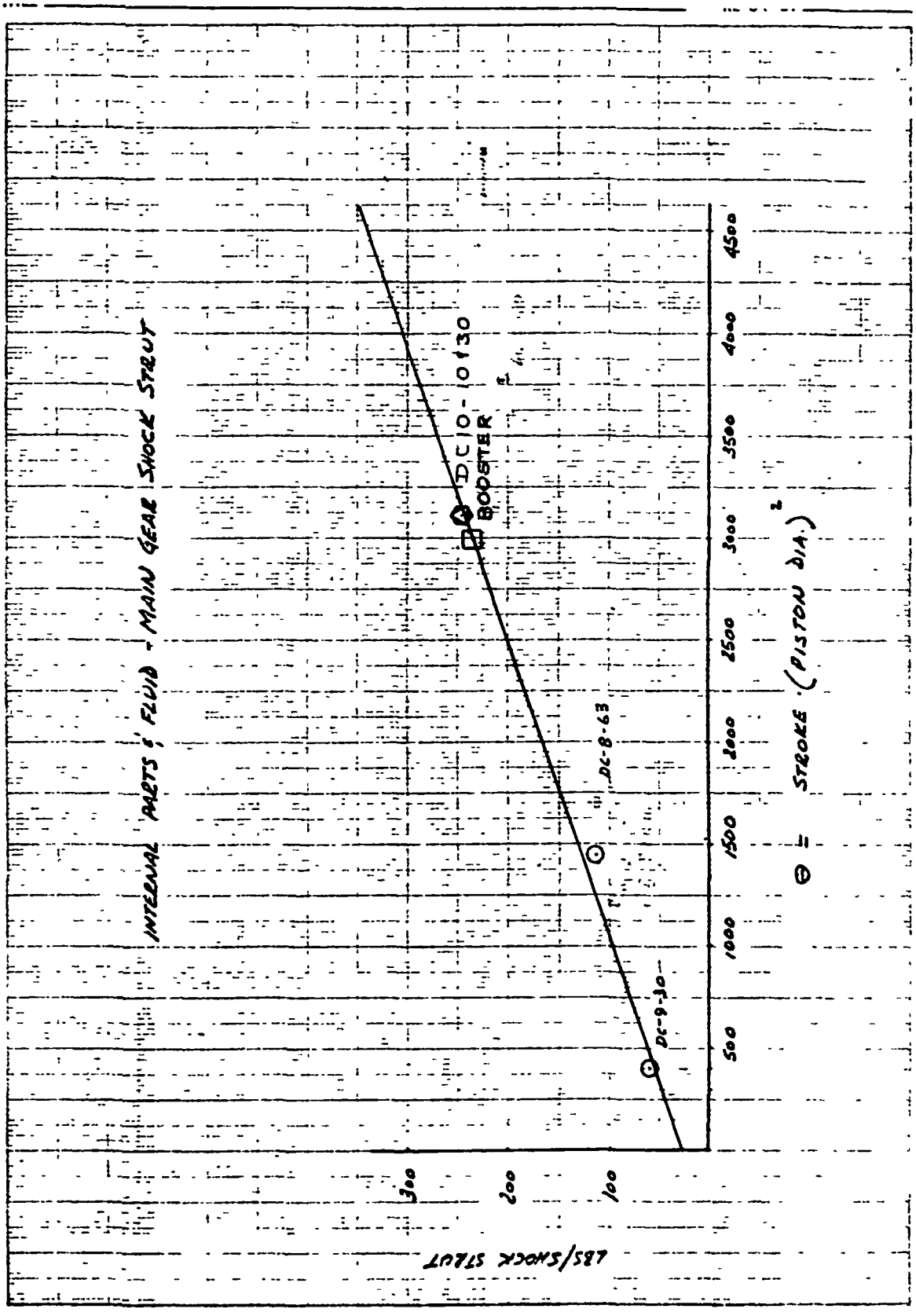
$\Theta = S(D_p)^2$

$= 30(10)^2$

$\Theta = 3000$

From graph -

Wt = 235 lbs OR 470 lbs/Vehicle


INTERNAL PARTS & FLUID - MAIN GEAR SHOCK STRUT
DC10-10 130
BOOSTER
DC-8-63
DC-9-30
Θ = STROKE · (PISTON DIA.)²
LBS/SHOCK STRUT
100
200
300
500
1000
1500
2000
2500
3000
3500
4000
4500

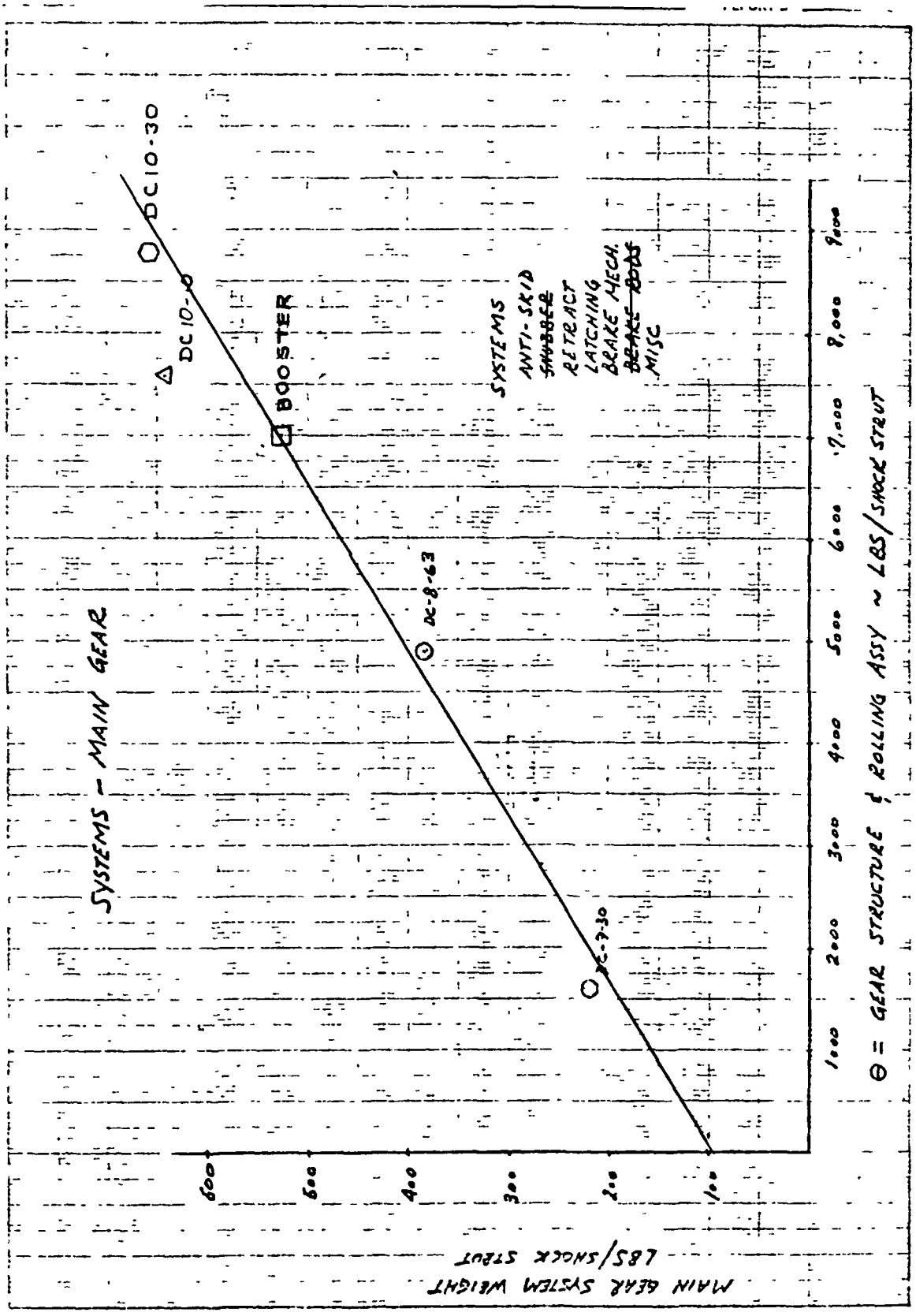
MAIN LANDING GEAR - SYSTEMS

SYSTEMS:
ANTI SKID
RETRACT
LATCHING
BRAKE

Wt GEAR STRUCTURE 8250
Wt ROLLING ASSY 5760
14,010 lb
2
7005 lbs/strut & RA

From graph

Wt = 525 or 1050 lbs/Vehicle


MAIN GEAR SYSTEM WEIGHT
LBS/SHOCK STRUT
SYSTEMS – MAIN GEAR
DC10-30
DC 10-10
BOOSTER
DC-8-63
DC-8-30
SYSTEMS
ANTI-SKID
SHIMMER
RETRACT
LATCHING
BRAKE MECH.
BRAKE BOLT
MISC
Θ = GEAR STRUCTURE & ROLLING ASSY ~ LBS/SHOCK STRUT

ROLLING ASSEMBLY WEIGHT DEFINITION

NOSE GEAR AND MAIN LANDING [illegible]
ASSEMBLY [illegible] AS [illegible]

		Wt	
TIRE	(SEE FIG 25) ref pg 2.5-47	[illegible]	[illegible]
Wheel	(SAME AS ORBITER, see vol II, MDC E0377)	182	lbs
BRAKES	ref pg 2.5-48	25[illegible]	[illegible]
AIR		20.	lbs
TOTAL ROLLING ASSY Wt/UNIT		720	lb
4 UNITS PER STRUT		x4	
TOTAL WT/STRUT		2880.	lb

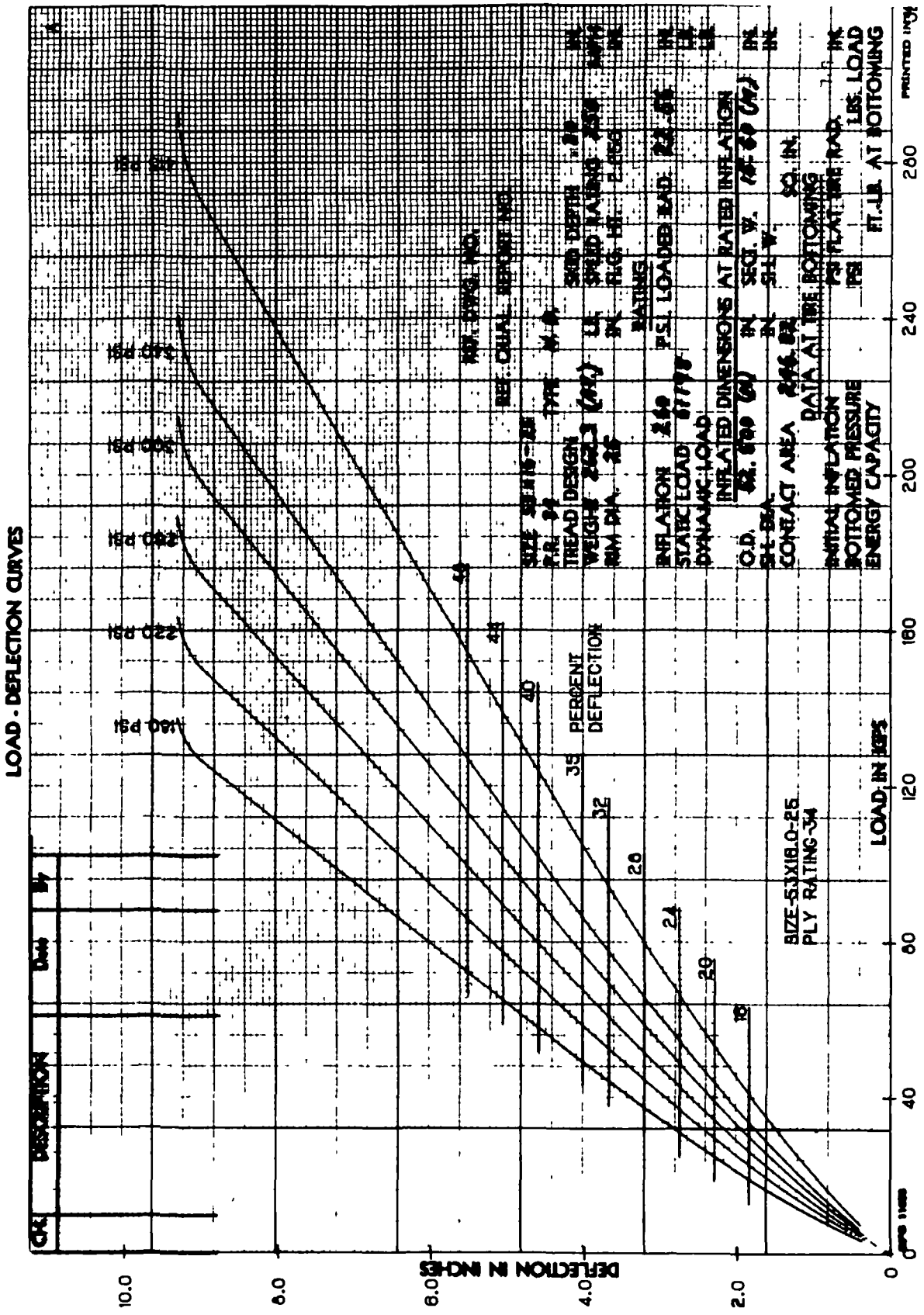

LOAD - DEFLECTION CURVES
LOAD IN KIPS
DEFLECTION IN INCHES
PERCENT DEFLECTION
SIZE-53X18.0-25
PLY RATING-34
INFLATION
STATIC LOAD
DYNAMIC LOAD
INFLATED DIMENSIONS AT RATED INFLATION
O.D.
SEC. W.
CONTACT AREA
RATIO AT TIRE BOTTOMING
INITIAL INFLATION
BOTTOMED PRESSURE
ENERGY CAPACITY
LBS. LOAD
FT.-LB. AT BOTTOMING

FIG. 4.2.3.-3

BOOSTER CONFIGURATION 20A

BRAKE ENERGY REQMT. & BRAKE WEIGHT

1. Mission Landing Wt. = 588,000 lbs.

   Landing Velocity = 180 Knots X 1.689 = 304 ft/sec

   K. E. = 1/2 MV^2 = $\frac{W\ V^2}{2\ g}$ = $\frac{588K}{64.4}$ X 304^2 = 846 X 10^6 ft. lbs.

   Assume equal capacity in each of 12 wheels, then

   K.E. per brake = 70.5 X 10^6 ft lb.

2. Use carbon composite heat sink from Goodyear data:

   $\frac{70.5 \times 10^6}{530,000}$ = 135 lbs. of heat sink per wheel.

   Density = .061 #/cu.in.

   Vol. = $\frac{135}{.061}$ = 2220 cu.in./brake

3. Use 53 X 16 rim dia. - 25" O.D. (Type VII)

   a) Assume: Wheel inside dia. = 23"

   b) Heat sink (brake) O.D. = 21.8 in. with 1.2 in. clearance for heat shield and air passage.

   c) Brake i.d. = 11 in.

4. Then: Length of heat sink portion of brake

   ℓ = 2220/ $(\overline{21.8}^2 - \overline{11}^2)$ = 6.27

   Pressure plate allowance = $\frac{2.50}{8.77}$

   Total brake length =

5. Total brake weight = 1.9 X 135 = 256# per wheel. (on 12 wheels)

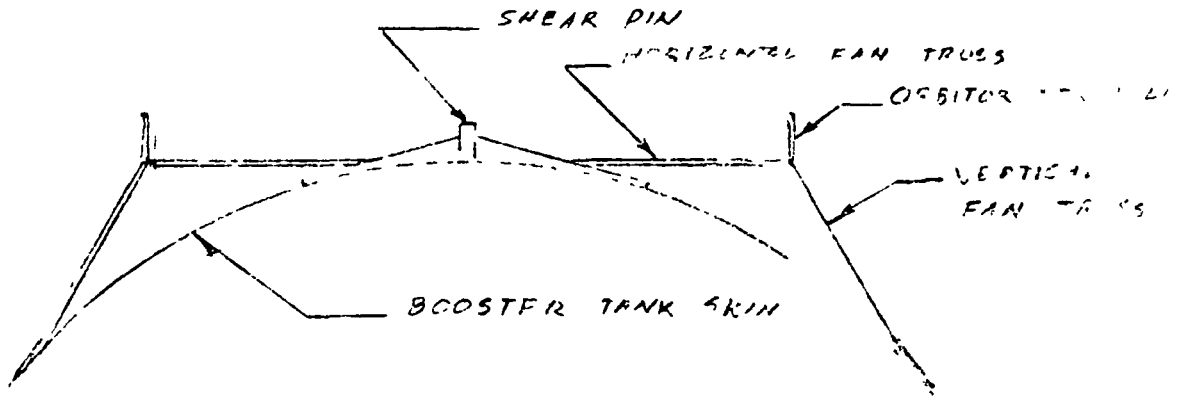
ORBITER ATTACH & SEPARATION SYSTEM

ITEM	WT-LB
* AFT ATTACH:	(2320)
VERTICAL TRUSS (2)	1153
HORIZONTAL TRUSS (2)	470
STRUT LINK FITTINGS (2)	247
TRUSS ATTACH PARTS	186
SHEAR PIN INSTALLATION	140
ORBITER STRUT LINK (2)	124
** FWD ATTACH.	(508)
BEAM ASSEMBLY	460
FITTING - PISTON RETAINER	48
** SEPARATION MECHANISM	
PISTON ASSEMBLY	(310)
CONTINGENCY 5%	(157)
TOTAL	3295

** L/O NO. 254AA86004
INTERSTAGE CONNECTON & SEPARATION MECHANISM

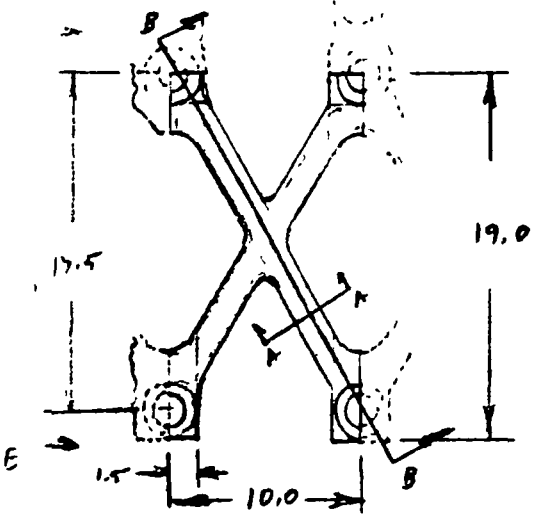
AFT ATTACHMENT, LAYOUT NO. 256-20-0006

WITH SUMMARY, DESIGN ALTERNATE NO 2



AFT TRUSS ASSEMBLY		2056
VERTICAL FAN TRUSS (2)	1153	
HORIZONTAL FAN TRUSS (2)	470	
STRUT LINK FITTINGS (2)	247	
FASTENERS	186	
SHEAR PIN INSTALLATION		140
ORBITER STRUT LINK (2)		124
TOTAL AFT ATTACH		2320 LB
TOTAL FWD ATTACH		508 LB
		2828 LB

FAN TRUSS END FITTING



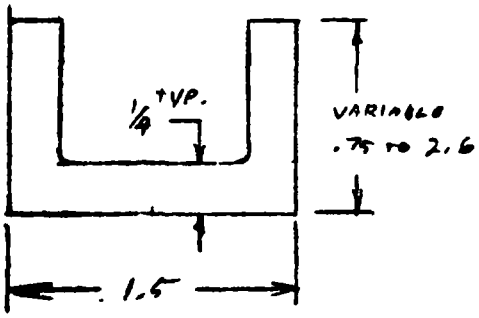
REPEATING SECTION AT ISOGRID ATTACH

X PATTERN AREA
= 1.5(13 + 11.5) = 38.2 IN²

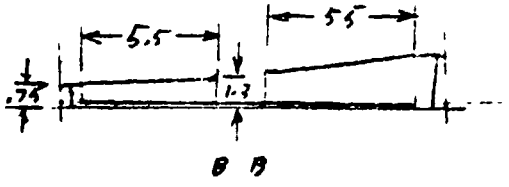
EDGE RIBS

$6.5\left[\left(\frac{.75+1.3}{2}\right)+\left(\frac{1.4+2.0}{2}\right)\right]a = 60$ in²

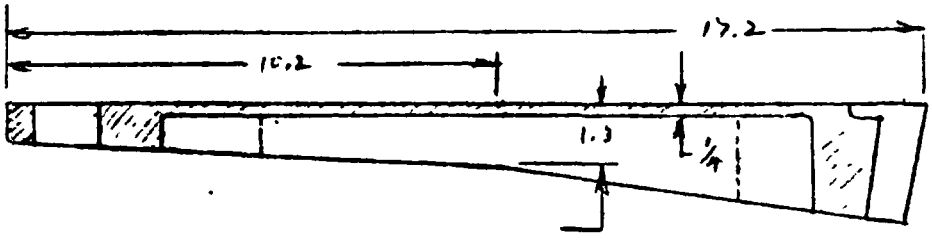
X PATTERN WT. = 60(.25)(.1) = 1.5 lb



A-A
SCALE 1/1



B B
SCALE = 1/10



X PATTERN END CLOSING BAR
SCALE 1/10.

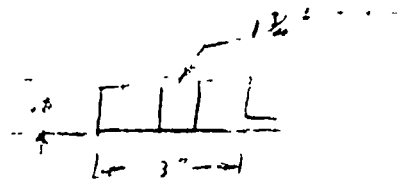
BASE = (12.5)(1.5)(.25)(.1)

FLANGE $\left[(7.0)\left(\frac{1.3+.9}{2}\right)+6.5\left(\frac{1.3+2.1}{2}\right)\right](.25)(.1)$ = .5 lb

$\left[(5.0)\left(\frac{1.0+1.3}{2}\right)+5.0\left(\frac{1.3+1.9}{2}\right)\right](.25)(.1)$ = .7 lb

1.2 lb.

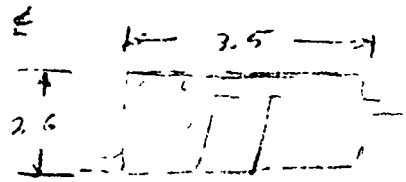
[illegible] TRUSS END FITTING



½ CORNER FEET – CANDOR END (TWO)

$$.8\left(1.5 \cdot 3.0 - \frac{.875^2 \pi}{2}\right)(.1)2 = .6 \text{ lb.}$$

CORNER FEET – TRUSS END (TWO) TO BOLT ℄



$$\left[2.6(3.5) - \left(\frac{[illegible]}{2}\right)\right](2.6)(.1)2$$

$= 3.0$ lb.

TOTAL REPEATING X SECTION

X-[illegible]	1.5
FEET (TWO)	.6
FEET (TWO)	3.0
	5.1

SIDE FAN TRUSS, 13 REPEATING SECTIONS = 66.3

[illegible] BAR (TWO) 2.4

TOTAL FAN TRUSS (ONE) = 68.7 lb

UPPER FAN TRUSS, 4 REPEATING SECTIONS = 20.4

[illegible] BAR (FOUR) = 4.8

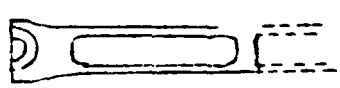
25.2 lb.

[illegible]

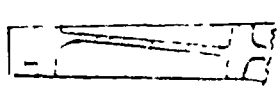
[illegible]

6 [illegible]

END FITTING



SCALE 1/10



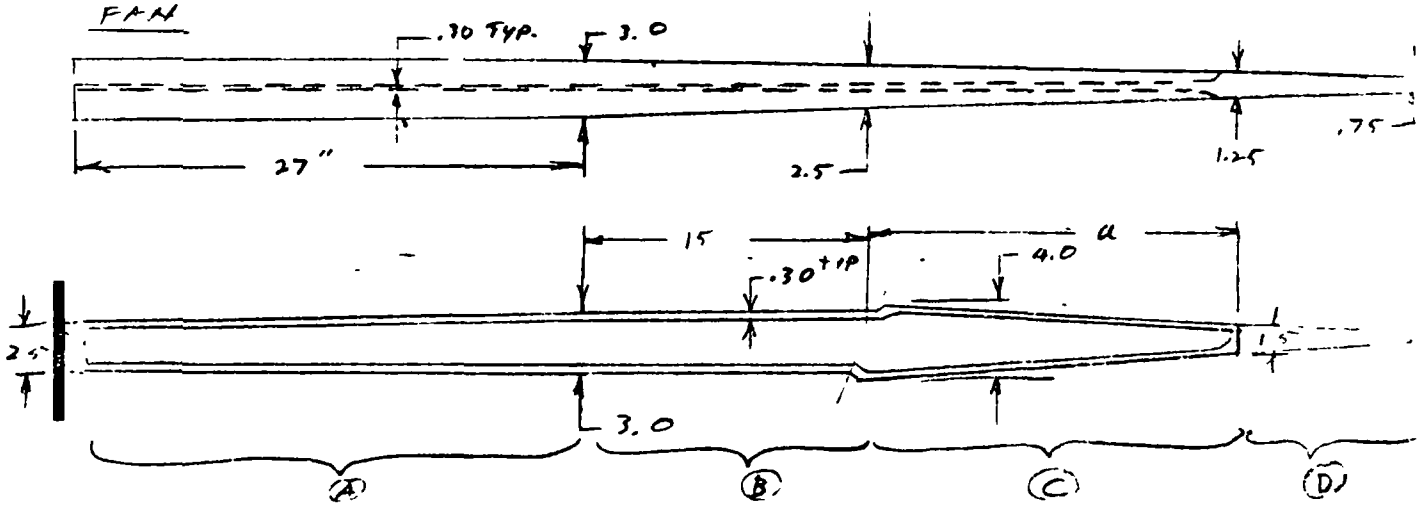
END BLOCK

$$\left[(3.2)(3.2) - \frac{.375^2\pi}{2}\right] 2.5(.1) = 2.3 \text{ lbs.}$$

$$\text{BAR}\left[(2.5)(2.5)(10) - 2.0(9.0)\left(\frac{.5+1.0}{2}\right) - (20)(9.0)\left(\frac{1.75+1.24}{2}\right)\right].1 = 3.2 \text{ lbs.}$$

TOTAL EBD = 5.5

FAN



TOTAL BAR

$$\text{A} = \left[\left(\frac{2.5+3.0}{2}\right)(3)(27) - \left(\frac{1.90+2.40}{2}\right)(2.70)(27)\right].1 = 6.6 \text{ lbs.}$$

$$\text{B} = 15\left[\left(\frac{3.0+2.5}{2}\right)(3.0) - \left(\frac{2.70+2.20}{2}\right)(2.4)\right](.1) = 3.6 \text{ lbs.}$$

$$\text{C} \quad u\left[\left(\frac{4.0+1.5}{2}\right)\left(\frac{2.5+1.25}{2}\right) - \left(\frac{3.40+.90}{2}\right)\left(\frac{2.20+.95}{2}\right)\right](.1) = .375u$$

u varies from 19.5 to 32 inches

C	AVERAGE = 25.75 (.375) =	10.0 lbs.	
B	=	3.6	
A	=	6.6	
END	=	5.5	
D	=	9.0	34.7
	NO REQ'D =		14
	SUB TOTAL		485.8

D: (20)(1.5)(3.0)(.1) = 9.0

$\left[(20)(1.5) + 10(.75)\right]\frac{7}{2}(.1) = 13.1$

END PLATE 22.1 lbs. 1 REQ'D 22.1

TOTAL MACHINED FAN 507.9

HORIZONTAL FAN TRUSS

X FITTINGS 5.1 LB. EA × 4 = 20.4 LB. (SEE P2.5-52)

X CLOSING BAR 1.2 EA × 4 = 4.8 LB. (SEE P2.5-51)

FAN, LESS END ⓒ = 24.7 × 6 REQ'D = 148.2

ⓒ BAR END = .375 (16)(6) = 36.0

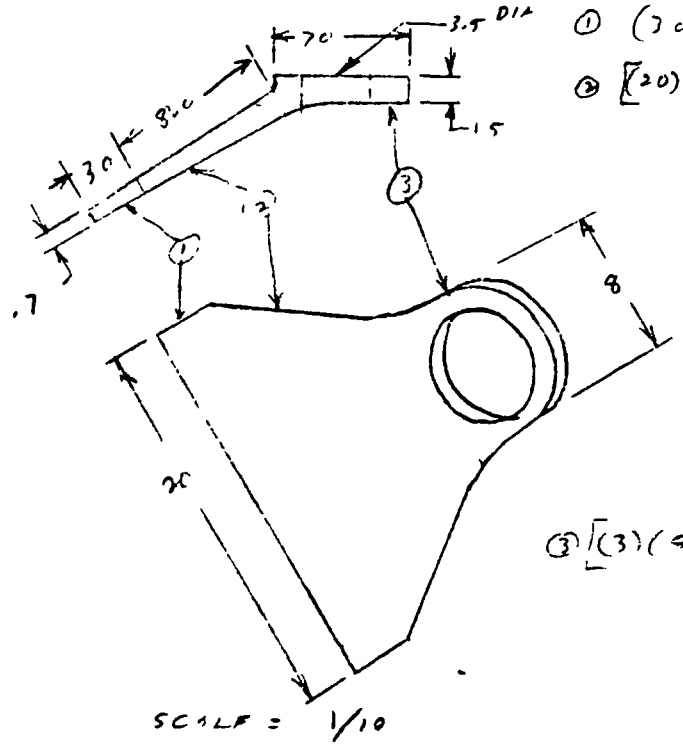
SUB TOTAL = 209.4

D, END PLATE

[(13.5)(1.5) + (9.0)(.75)] 9 (.1) = 25.7

TOTAL - HORIZONTAL FAN TRUSS 235.1 LB.

LUG FITTINGS

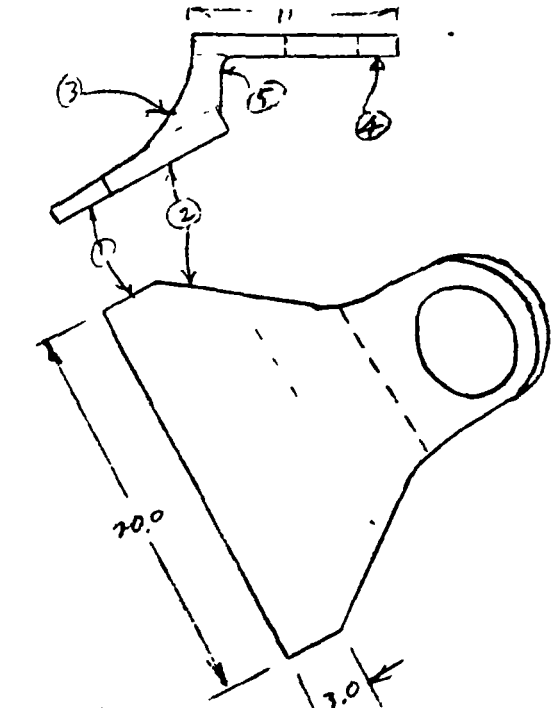


① (3.0)(20)(.9)(.1) = 4.8

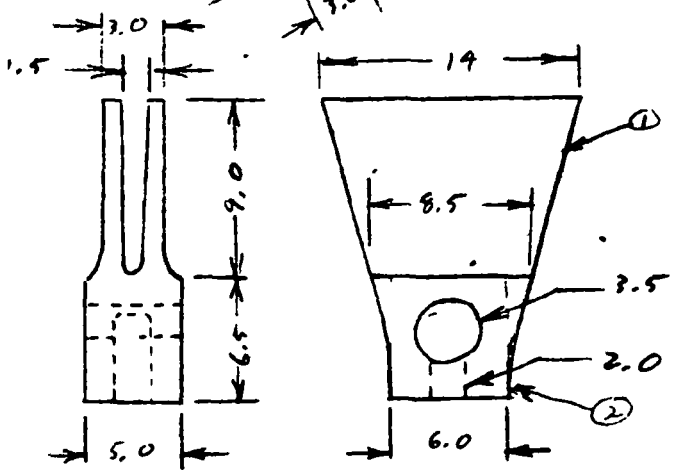
② [(20)(8) + 9(1.5)] 8/2 (.1) = 11.2

③ [(3)(9) + 4²π/2 − (.75)²π] 1.5 (.1) = 5.7

21.7



①	SEE PREVIOUS PAGE	4.8
②	"	11.2
③	$\left(\frac{(2.5)(4.0)}{2}\right)(12)(.1)$	6.0
④	$\left[(7)(8) + \frac{4^2\pi}{2} - 1.75^2\pi\right](1.5)(.1) =$	9.1
⑤	$\frac{(1.7)(3.0)}{2}(4.0)(.1) =$	1.2
		32.3 LB.



① $\left(\frac{8.5+14}{2}\right)\left[(3.0)-\left(\frac{1.5+.75}{2}\right)\right](9.0)(.1)$
$= 19.0$ LB.

② $(5.0)(6.0)(1.5) = 195$ IN^3
$-(1.75)^2\pi(5.0) = -48$
$-1.0^2\pi(2.0) = -6$
$1.5(4)(5) = \underline{30}$
219 IN^3 = 21.9 LB.

TOTAL FITTING. 40.9 LB.

SHEAR PIN (STEEL)

$[1^2\pi(10) + 3^2\pi(.5)].289 = 13.1$ LB.

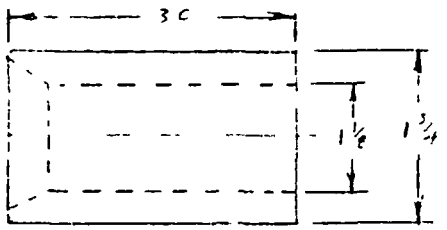
SLEEVE (STEEL)

$(2^2 - 1^2)\pi(5.75)(.289) = 15.6$ LB.

ATTACHMENTS

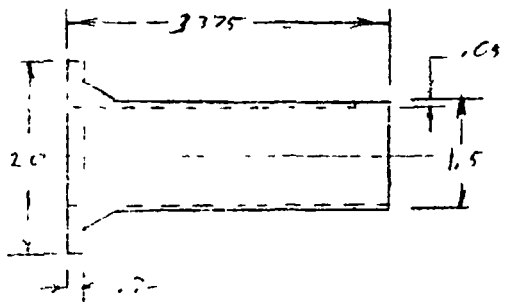
BLIND FASTENERS FOR ISOGRID

SPACER - AL



wt. = $\left(.875^2 - .5625^2\right)\pi(.30)(.10) = 0.42$

FABRICABLE FILLET - STEEL

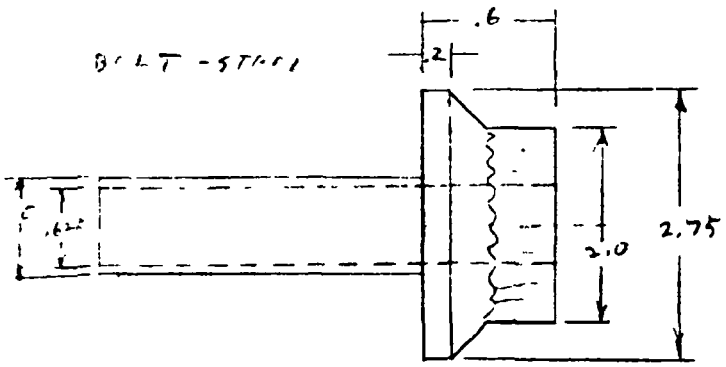


wt. = $(.75^2 - .7^2)\pi(.375)(.289) = .22$

$(1.0^2 - .75^2)\pi(.2)(.289) = .08$

.30

BOLT - STEEL



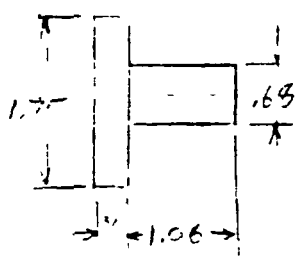
$(.5^2 - .3125^2)(\pi)(2.375)(.289) = .26$

$(1.0^2 - .3125^2)\pi(.6)(.289) = .49$

$(1.375^2 - 1.0^2)\pi(.3)(.289) = .25$

1.15

NUT - STEEL



$\frac{1.75^2}{4}\pi(.375)(.250) + \frac{.65^2}{4}\pi(1.06)(.237) = .38$

WASHER - STEEL

$\left(\frac{2.75^2 - 1.125^2}{4}\right)\pi(.1)(.289) = .14$

TOTAL FASTENERS 2.32 lbs.

TOTAL FASTENERS:

VERTICAL FAN = 28

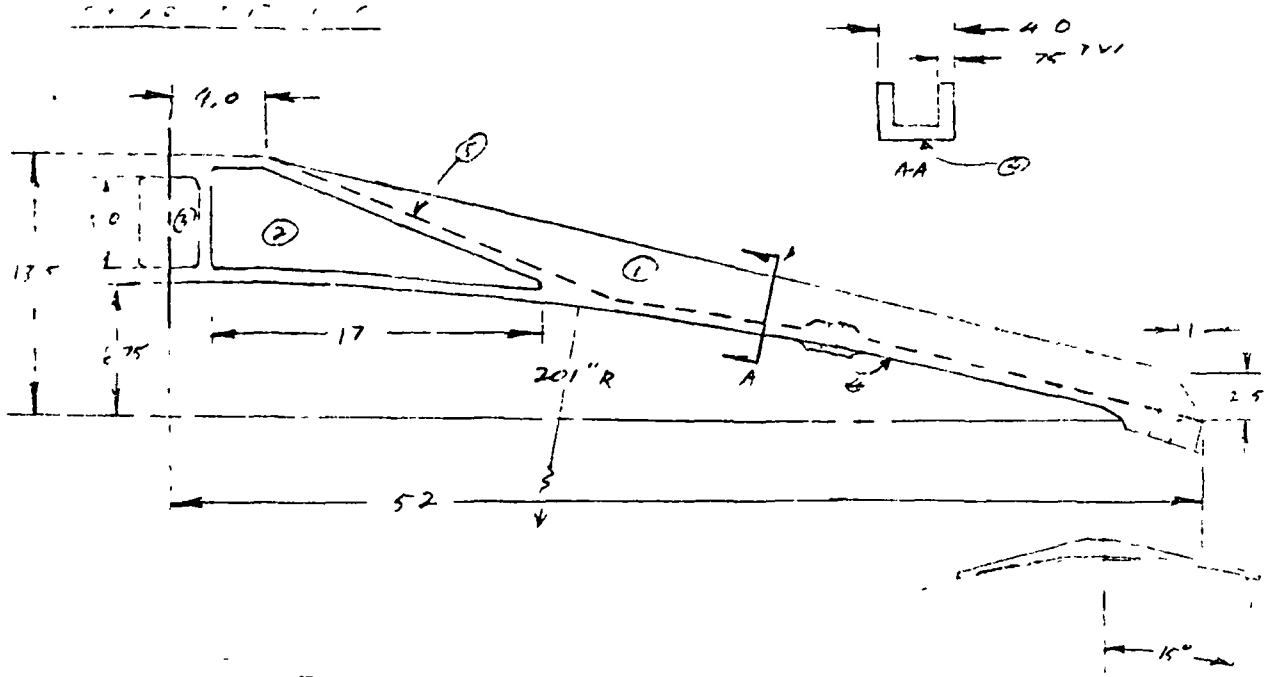
HORIZONTAL FAN = 12

40

TOTAL WT. = 40(2.32) = 92.8

TRUSS SUMMARIES		WT./SIDE	BOOSTER TOTAL
VERTICAL FAN TRUSS MACHINED PART		576.6	1153.2
X ISOGRID ADAPTORS	68.7		
14 STRUTS @ 34.7 EACH	485.8		
STRUT END WEDGE	22.1		
VERTICAL FAN END FITTINGS		54.0	108 C
HORIZONTAL FAN TRUSS MACHINED PART		235.1	470.2
X ISOGRID ADAPTORS	25.2		
6 STRUTS @ 30.7 EACH	184.2		
STRUT END WEDGE	25.7		
HORIZONTAL FAN END FITTING		40.9	81.8
FITTING SLEEVE & PIN		28.7	57.4
FASTENERS 2.32 EA X 40		92.8	185.6
			2056.2

X THESE ITEMS COMBINED IN SUMMARY (247.2*)



SIDE PLATES ①

$$A = 8(13.5) + \left(\frac{13.5+2.5}{2}\right)(48)(2) - \frac{201^2}{4}\left(\frac{30\pi}{180} - \sin 30°\right) - 5.25(2)(2) - 5.0(3.5)$$

TOTAL STEEL UNIT SINC SEC. ③ ②

$$- 5.25(17-4.25) - (1)(2.5) = 105 + 768 - 237 - 21 - 15 - 61$$

②

$$= 533 \text{ IN}^2$$

$t = .75$

$$\text{WT.} = .75(533)(2 \text{ sides})(.1) = 80.0 \text{ lb.}$$

$$\text{PANEL } ② - ③ = 3(5) + 4(5.25) + (17-4.25)(5.25) = 15 + 21 + 67 = 103 \text{ lb}$$

$$\text{WT.} = 103(.75)(.1) = 7.7 \text{ lb.}$$

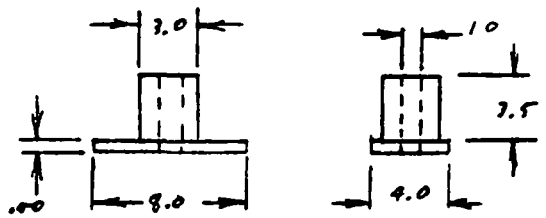
$$\text{WEB } ④ = \frac{\pi(201)(30)}{180}(4-1.5)(.75)(1) = 19.7 \text{ lb.}$$

$$\text{WEB } ⑤ = 20(2.5)(.75)(.1)(2) = 7.5 \text{ lb.}$$

PARTS

$50(2.5)(.75)(.1)(2)$	=	1.9
$4(4)(1.5)(.1)$	=	1.6
$1^2\pi(.75)(4)(.1)$	=	1.0
TOTAL CHAMBER FITTING		119.4
ATTACHMENTS = 2.32(4)		9.3

SHEAR PIN STEEL, ρ = .283



wt. = $[1.5^2\pi(3.5) + (4.0)(8.0)(.5) - 5^2\pi(4.0)].283 = [24.7 + 16 - 7.14].283$

= 10.6 LB.

ATTACHMENTS - four ½" H.S. BOLTS WITH 1.5" GRIP

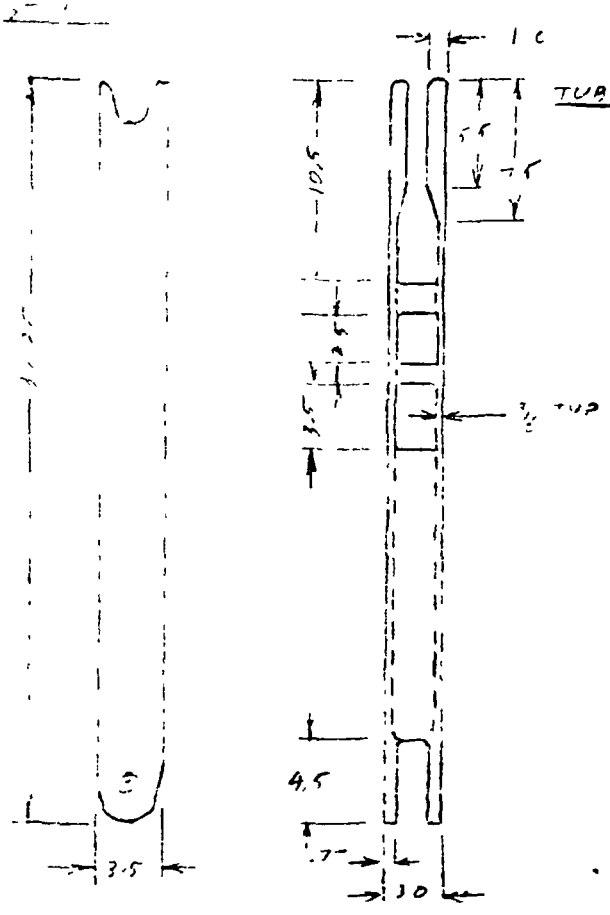
wt. = $[.5^2\pi(.5) + .25^2\pi(2.25)].283$ = .14 LB EA

NUT & WASHER = .06 LB.

TOTAL = (.14 + .06) 4 = .8 LB.

SHEAR PIN INSTALLATION SUMMARY

FITTING	119.4
PIN	10.6
ATTACHMENTS	9.3
	.8
	140.1 LB.



TUBE SIZING CHECK

$\sigma = \frac{P}{A}$

$P = 1,044,000$ pounds

$A = (3.5)(.375)2 + (3.0 - .75)(.375) = 4.32$

$\sigma = \frac{526\ 728\ \text{lb.}}{4.32\ \text{in}^2} = 122,000$ psi

OK

WEIGHT CALC.

TUBE = 4.32(39.25)(.283) = 48.0 lb.

CUTTOUTS = (3.5 + 2.5 + 10.5 + 4.5)(3.0 − .75)(.375)(.283) = − 5.0

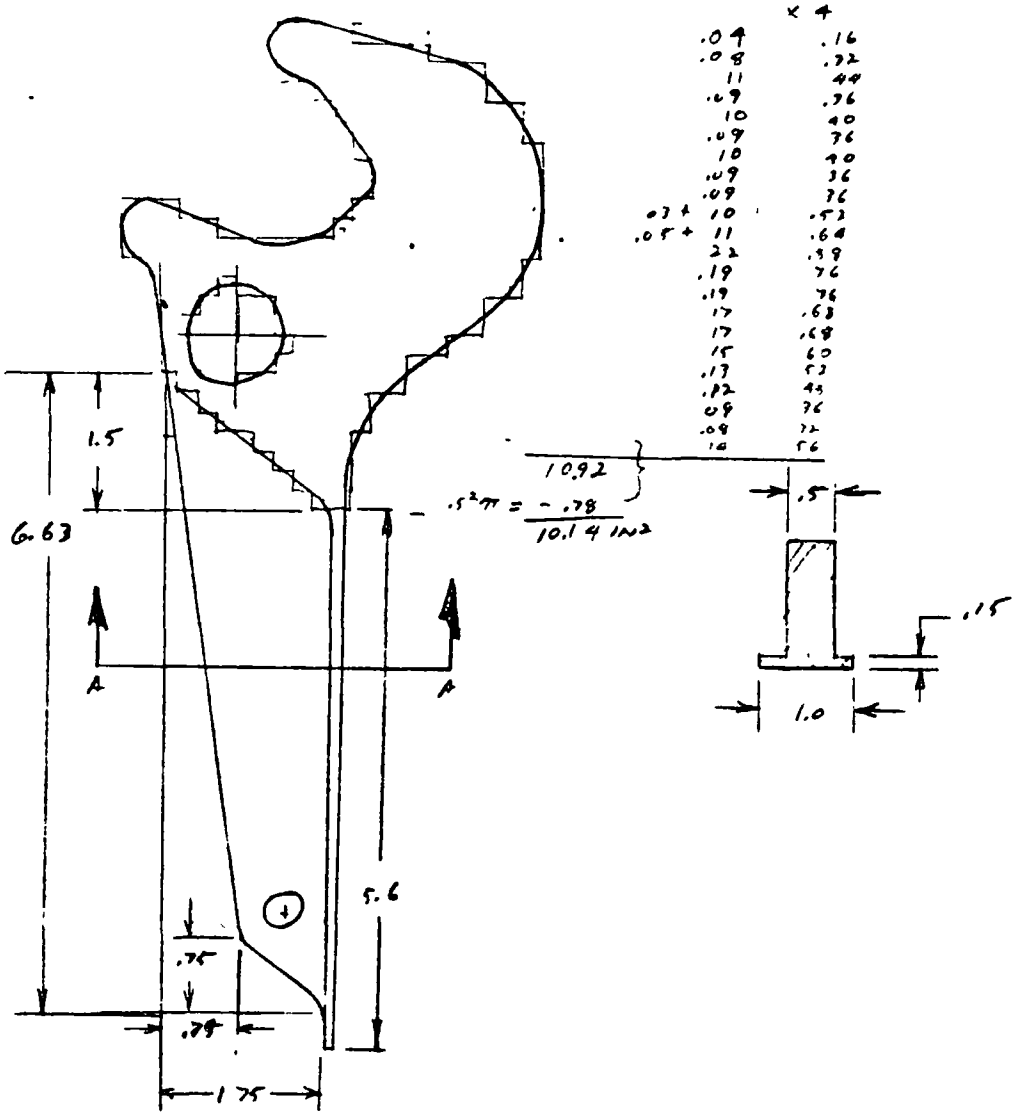
BEEF-UP, UPPER = .625(3.5(6.5)(.283)(2) = + 8.1

BEEF-UP-LOWER = .375(3.5)(4.5)(.283)2 = + 3.4

TOTAL 54.5 lb.

L/O 254 AA B 6004

LATCH



HEAD WT. = 10.14(1.0)(.289) = 3.0 LB.

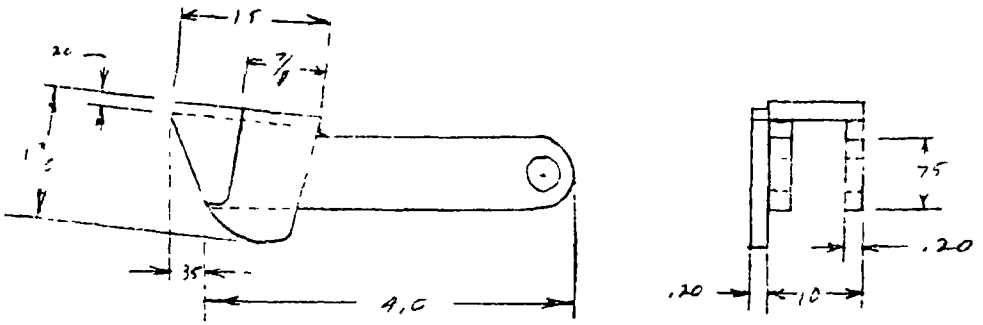
ARM = [(5.19)(1.75) − (10)(.75)(½) + 1.5(1.75)(.5) − (6.63−.75)(.75)(.5)](.5)(.289)

= [8.97 − .375 + 1.31 − 2.22](.5)(.289 = 1.1 LB.

STIFFENER = 5.6(1.0)(.15)(.289) = .3

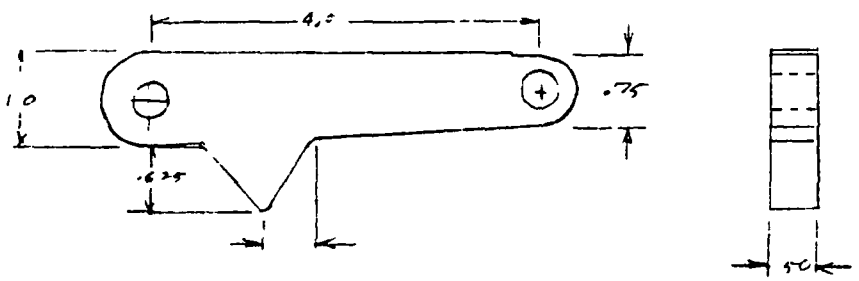
TOTAL = 4.4 LB.

LINK, UPPER STEEL, $\rho = .283$



$$w_1 = [(.75)(4.0)(.2)(2) + 1.5(1.5)(.2)(2) + .75(.2)(2) + 1.5(1.0)(.20)](.283) = .50 \text{ lb.}$$

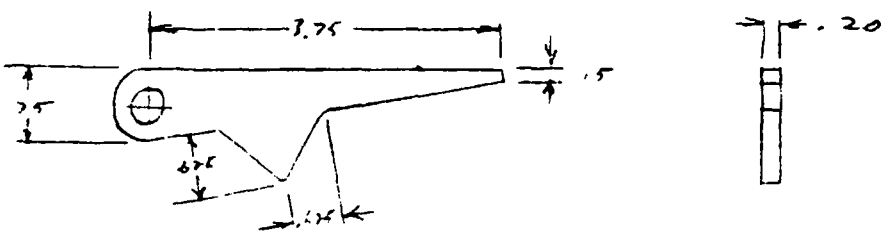
LINK, LOWER STEEL, $\rho = .283$



$$A = 4.0\left(\frac{1+.75}{2}\right) + \frac{\pi}{2}\left(.75^2 - .375^2\right) + .625(.625) = 4.6$$

$$w_1 = 4.6(.50)(.283) = 0.7 \text{ lb.}$$

CLEVIS CENTER LUG STEEL, $\rho = .283$



$$w_1 = \left[3.75\left(\frac{.15+.75}{2}\right) + \frac{.375^2}{2}\pi + .625^2\right](.20)(.283) = .13 \text{ lb}$$

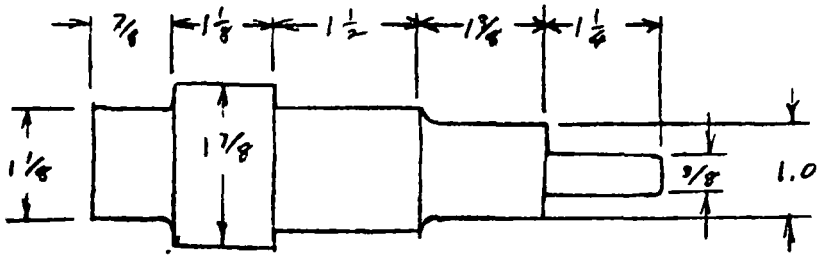
SPRING:

4 INCH RELAXED .10 INCH DIA WIRE = 40 ACTIVE COILS 7/8 DIA.

$$WT. = \left(\frac{.375^2 - .175^2}{2}\right)\pi(4.0)(.283) = .25 \text{ LB EACH.}$$

TWO REQ'D = .5 LB.

ACTUATOR



$$VOL = \left[\frac{1.125^2}{4}\left(\underset{2.125}{.875} + 1.5\right) + \frac{1.875^2}{4}(1.125) + .5^2(1.375) + \frac{.375^2}{4}(1.25)\right]\pi = 2.2 \text{ IN}^3$$

AVERAGE DENSITY = .10

WT. = .22 LB.

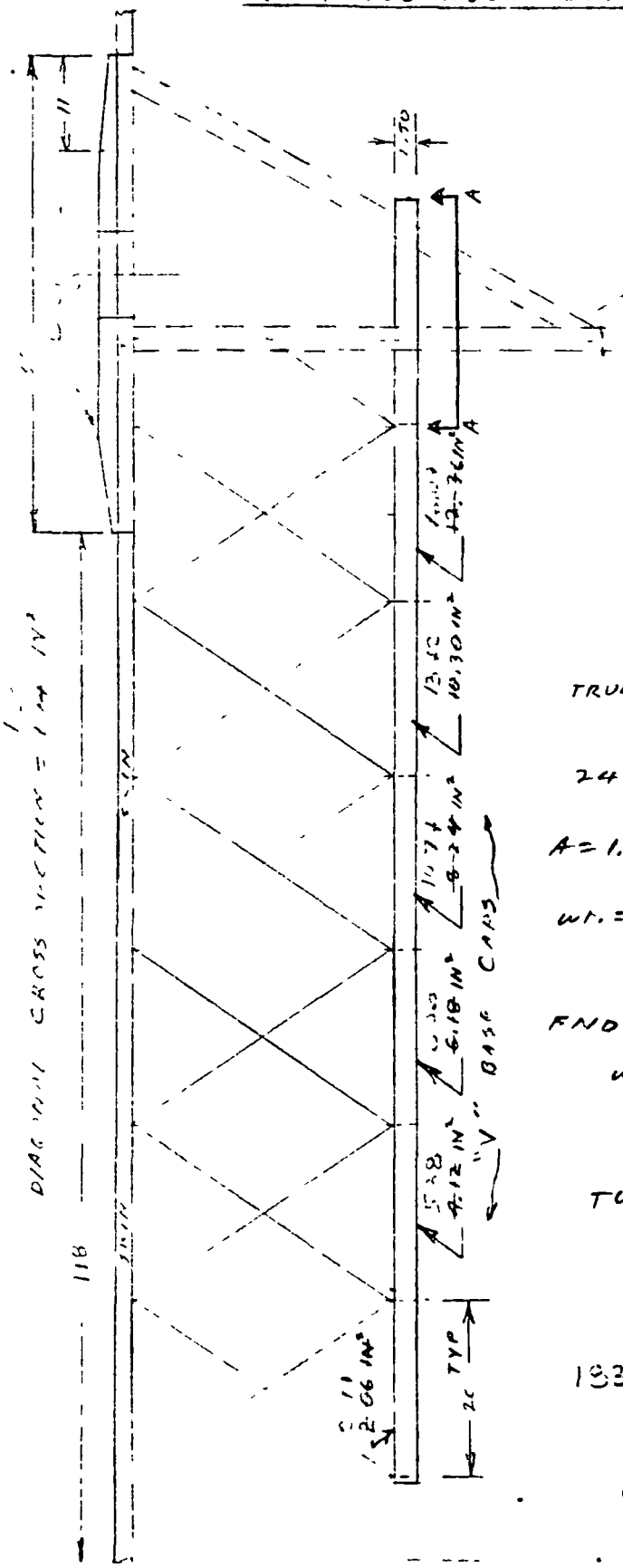
MISC. & ATTACH PARTS = 1.0 LB.

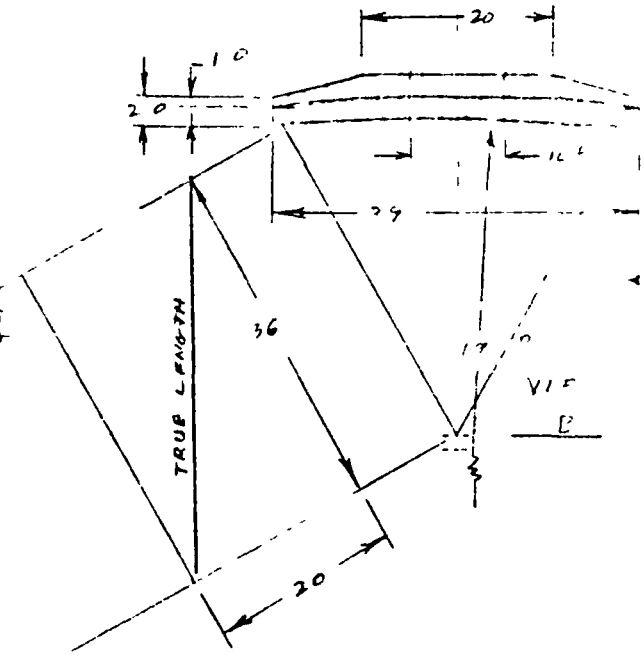
LATCH SUMMARY

LATCH	4.4
LINK-UPPER	.5
LINK-LOWER	.7
LOCK	.2
ACTUATOR	.3
SPRINGS, PINS & ATT. PTS.	1.5
	7.6 LB.
STRUT	54.5
ORBITER STRUT LINK	62.1 / STRUT (2 REQ)

TOTAL IN SUMMARY 124.2 ± B

V TRUSS ASSEMBLY L/O No 256-20-0017





TRUE DIAGONAL = $\sqrt{36^2 + 20^2}$ = 41.16

24 REQUIRED + 4 EQUIVALENTS AT ...

A = 1.14 IN²

WT. = 1.14(41.16)(1) = 47 LB each
×28 = 131.6 LB.

END FITTINGS = .92 LB ea, 2 PER ...

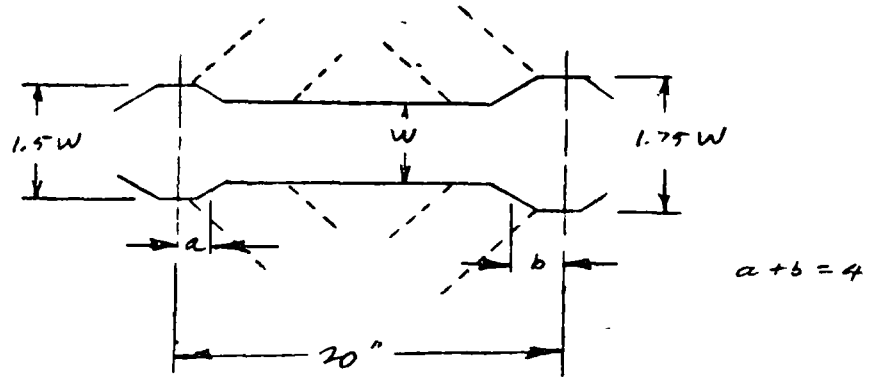
WT. = 28(2)(.92) = 51.6

TOTAL DIAGONALS: 131.6
51.6
183.2

$183.2\left(\frac{1.80}{1.14}\right) = 289.2$

VIEW A

'V' BASE CAPS



BASIC CROSS-SECTION NOTED ON PAGE 2

DIAGONAL ATTACH BEEF-UP = $\frac{(1.75+1.5)}{2} W \frac{4}{20} \ell = .325\, W\ell$

THEN BEEF-UP WT. = .325 × CAP WEIGHT

CAP WT. = $1.325 A \ell \rho = (1.325)(20)(.1) A = 2.65 A$

CAP	AREA	WEIGHT	
1	12.36	32.7 × (16.09 / 12.36) =	42.6
2	10.30	27.3 × (13.42 / 10.30) =	35.6
3	8.24	21.9 × (10.79 / 8.24) =	28.5
4	6.18	16.4 × (8.06 / 6.18) =	21.4
5	4.12	10.9 × (5.38 / 4.12) =	14.3
6	2.06	5.5 × (2.71 / 2.06) =	7.2
		~~114.7~~	149.6

TRUSS TOTAL

DIAGONALS	~~183.2~~	289.2
CAPS	~~114.7~~	149.6
	~~297.9~~	438.8

ATTACH PARTS – TRUSS TO INTERSTAGE

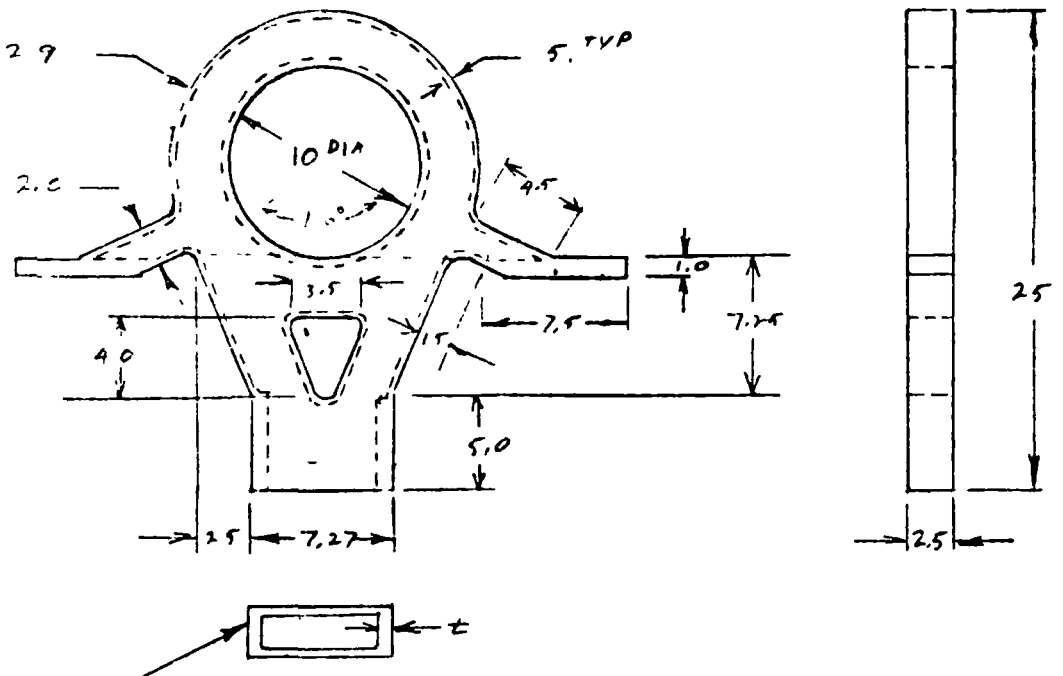
ASSUME 1.5 LB. AT EACH INTERFACE
4 POINTS FWD, 10 AFT

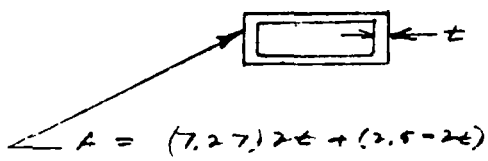
WT. = 14 (1.5) = 21 LB.

INSTALLED ASSEMBLY WEIGHT = ~~319.9 LB.~~ 460#

VIEW A-A P1

EJECTOR PISTON RETAINER FITTING.





$A = (7.27)2t + (2.5-2t)2t = 14.4$

$t = .90$

FITTING WT, BY PARTS:

UPPER & LOWER PLATES,

HOLLOW CIRCLE $= \left[\frac{(15.8^2 - 10^2)\pi}{4} - \frac{12.9^2}{2}\left(\frac{106\pi}{180} - \sin 106^\circ\right)\right] 2(.5)(.1) =$ 20.0 LB.

MATERIAL SUPPLIER $= \left[7.5(2.5)(1.0) - \frac{1.5}{2}(1.0)(2.5)\right] 2(.1)$

$+ \left(\frac{9.5+1.5}{2}\right)(.50)(2.0)(2)(.1) + 4.5(2.5)(.50)(.1)2 + 1.5(2.5)(.5)(.1)(2)$

$= 3.38 + .60 + 1.13 + .38 =$ 5.5 LB.

OUTER CIRCUMFERENCE $= \left[15.8\pi - \pi(7.9)(106/180)\right] 2.5(.5)(.1) =$ 4.4 LB.

INNER CIRCUMF. $= \left[10\pi(2.5)(.5)(.1)\right] =$ 3.9 LB.

CAP PLATE $= 14.92(5)(.1) =$ 7.2 LB.

WEB PLATE $= \left[(2.27+7.27)(7.25) - (3.5)(4.0)\right](.5)(.1) + \left(3.5^2+7.25^2\right)^{1/2}(2.5)(.5)(.1)2$

$+ \left\{\left[\frac{1}{2}(7.5)\right]^2 + 4.0^2\right\}^{1/2} + 3.5\Big\}(2.5)(.5)(.1) = \frac{6.38 + 1.92 + .99}{\text{TOTAL}} =$ 9.2 LB.

DOUBLER SUPPORT - SKIN INSERT

AREA = $39\left(\frac{55+33}{2}\right) = 1715\ IN^2$

$t = 2.25$ IN.

WT. = $1715(2.25)(.1) =$ 386 LB.

SKIN (ISOGRID) REMOVED

$\bar{t} = .288$

WT. = $1715(.288)(.1) =$ 49.4 LB.

SUMMARY - AFT ORBITAL SUPPORT

TRUSS ASSEMBLY	460
PISTON FITTING	48
TOTAL =	508

INTERSTAGE SEPARATION

DRWG NO 25YAA86000Y

SUMMARY	WT (LBS)
BRKT SECTION	36.3
RAM SPRING LOCK	.6
LOCK PISTON PLATE	3.2
LOCK PISTON ASSY	20 2
LOCK ASSY COMPRESSION SPRING	
8 RAM RETAIN SPRING	5.8
RAM ASSY	97.5
HOUSING ASSY NO 1	63 6
HOUSING ASSY NO. 2	41.3
HOUSING ASSY NO 3	9 2
[illegible] NO 4	10 1
DOGS (4 REQ)	5.2
MISC	2.1
	295.6
PLUS CONTINGENCY (5%)	14 4
TOTAL	310.0

DRWG NO. 254AA96004

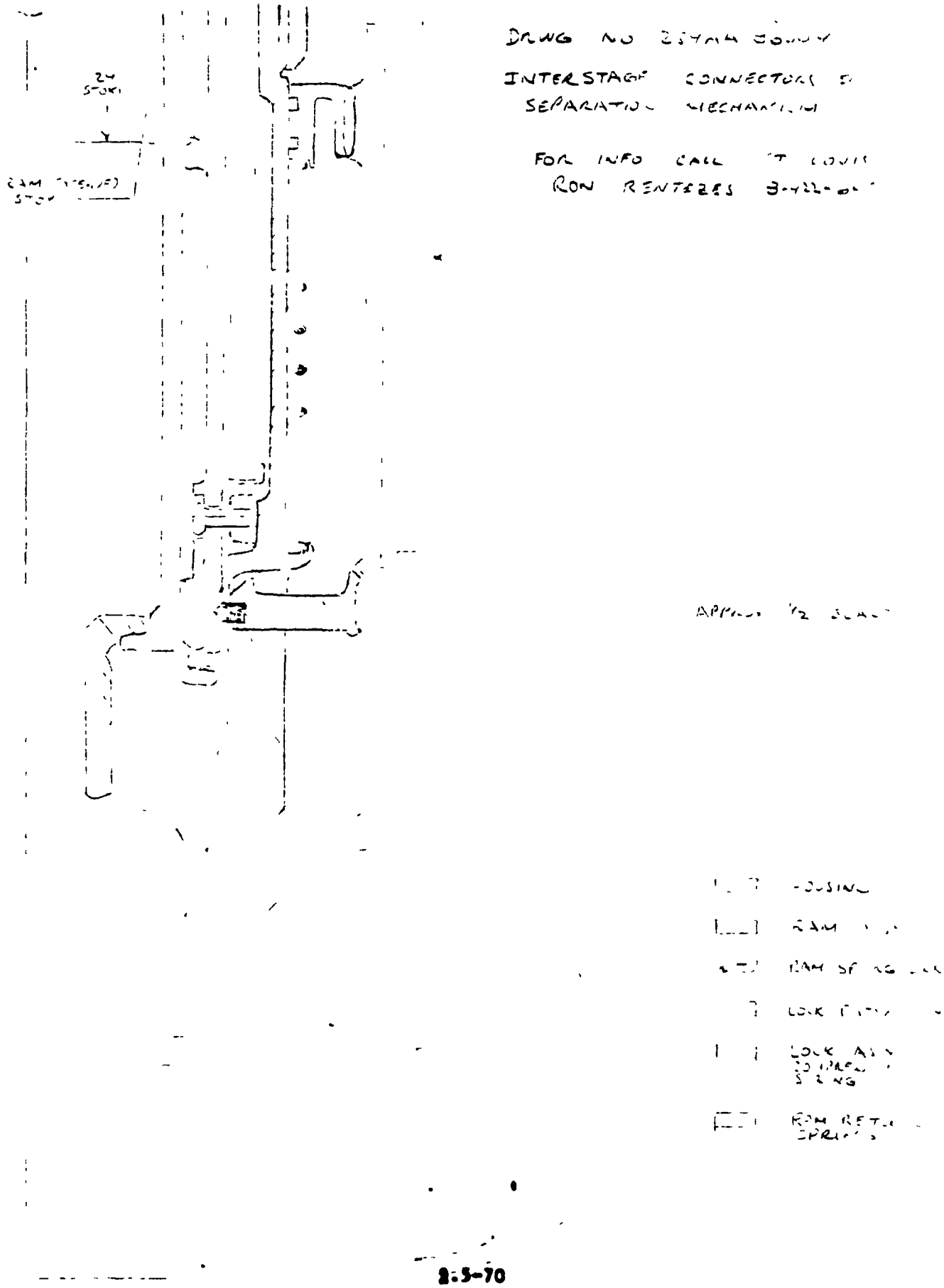
INTERSTAGE CONNECTORS & SEPARATION MECHANISM

CALLED ROIN RENTERIS AT ST LOUIS
PHONE 9-422-6458

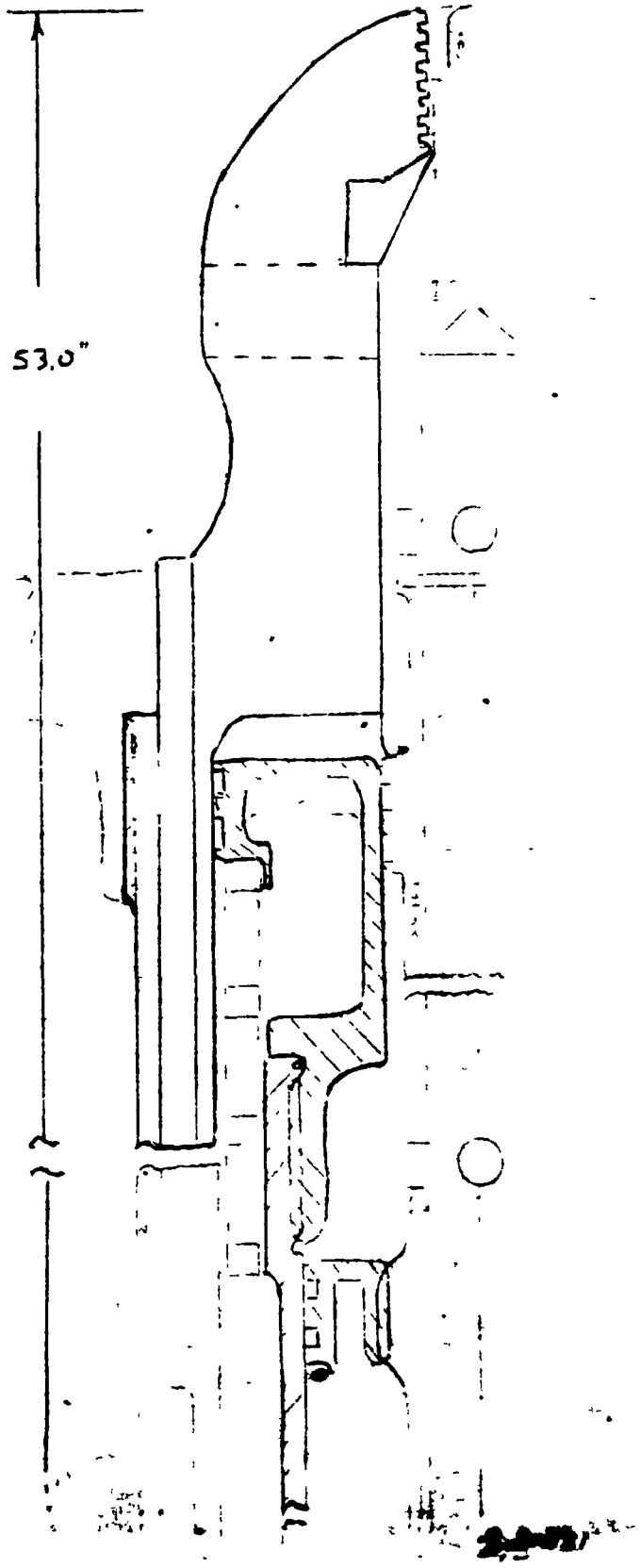
HE SAID TO CONSIDER ENTIRE ASSY TO BE OF STEEL, EXCEPT SOME PORTION OF CENTER ROD MAY BE ALUMINUM

ALSO HE HAD THE FOLLOWING INFORMATION

1. RAM RETURN SPRING
   CONSIDER 9" SOLID HEIGHT
2. LOCK ASSY COMPRESSION SPRING
   CONSIDER 3.5" SOLID HEIGHT & 0.2" DIA
3. ESTIMATED WT = 360 LBS.


DRWG NO
INTERSTAGE CONNECTORS
SEPARATION MECHANISM
FOR INFO CALL
RON RENTEZES
APPROX 1/2 SCALE
HOUSING
RAM
RAM SPRING
LOCK
LOCK ASSY
RAM RETURN SPRINGS

DRWG No. 254AA86004
INTERSTAGE CONNECTORS & SEPARATION MECHANISM



APPROX ½ SCALE

[illegible] STAGE SEPARATION
DRWG NO 254AA36004

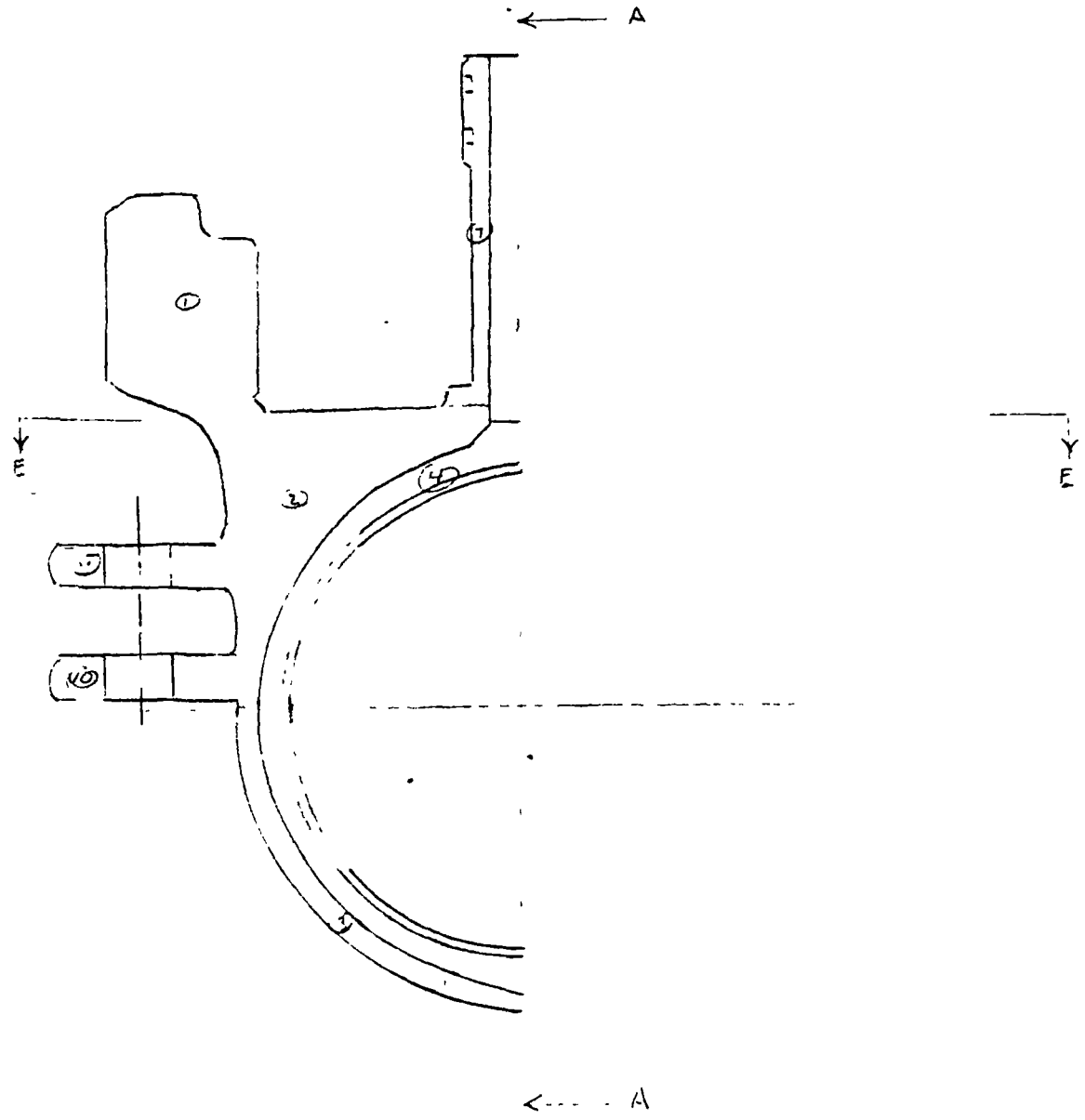
BREACH SECTION

			VOL (IN³)
1	$V = [(1.8)(2.4) - (.5)(.6)][1.7] \times 2$	=	13.7
2	$V = [\frac{1}{2}(.6)(1.0) + \frac{1}{2}(.8+2.8)(2.1) + \frac{1}{2}(.8+.35)(1.2)][.5] \times 2$	=	4.8
3	$V = (4.9)(.3)(.5) \times 2$	=	1.5
4	$V = .785[(5.5)^2 - (5.3)^2][7.8]$	=	14.1
5	$V = .785[(6.6)^2 - (6.0)^2][8.1]$	=	48.4
6	$V = .785(6.4)^2(.5) + .785(3.0)^2(.5)$	=	19.6
7	$V = .785(1.2)^2(.2) + .785(1.05)^2(2.5)$	=	
	$+ .785(1.7)^2(0.2) - .785(.7)^2(3.9)$	=	2.0
8	$V = .785(1.7)^2(1.3)$	=	2.9
9	$V = [\frac{1}{2}(3.3)(3.7) \times 2 - .785(.75)^2][.5] \times 2$	=	11.7
10	$V = [\frac{1}{2}(3.8)(2.1) \times 2 - .785(.75)^2][.5] \times 2$	=	7.5
	V_T	=	126.8

ASSUME MATERIAL STEEL

$WT = (126.8\ in^3)(286\ lb/in^3) = \underline{36.3\ LBS}$

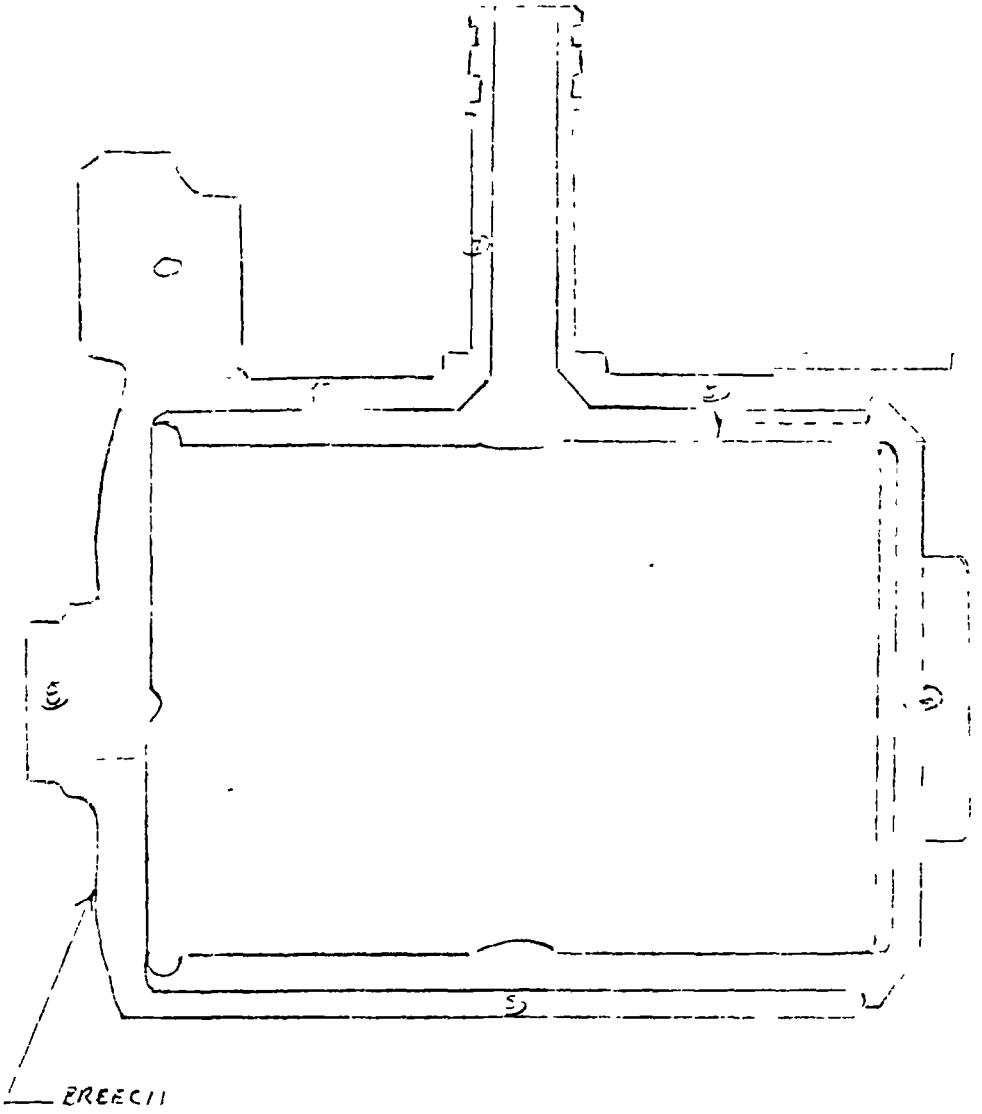
DRWG NO 254AA96004



½ SCALE

BREECH SECTION

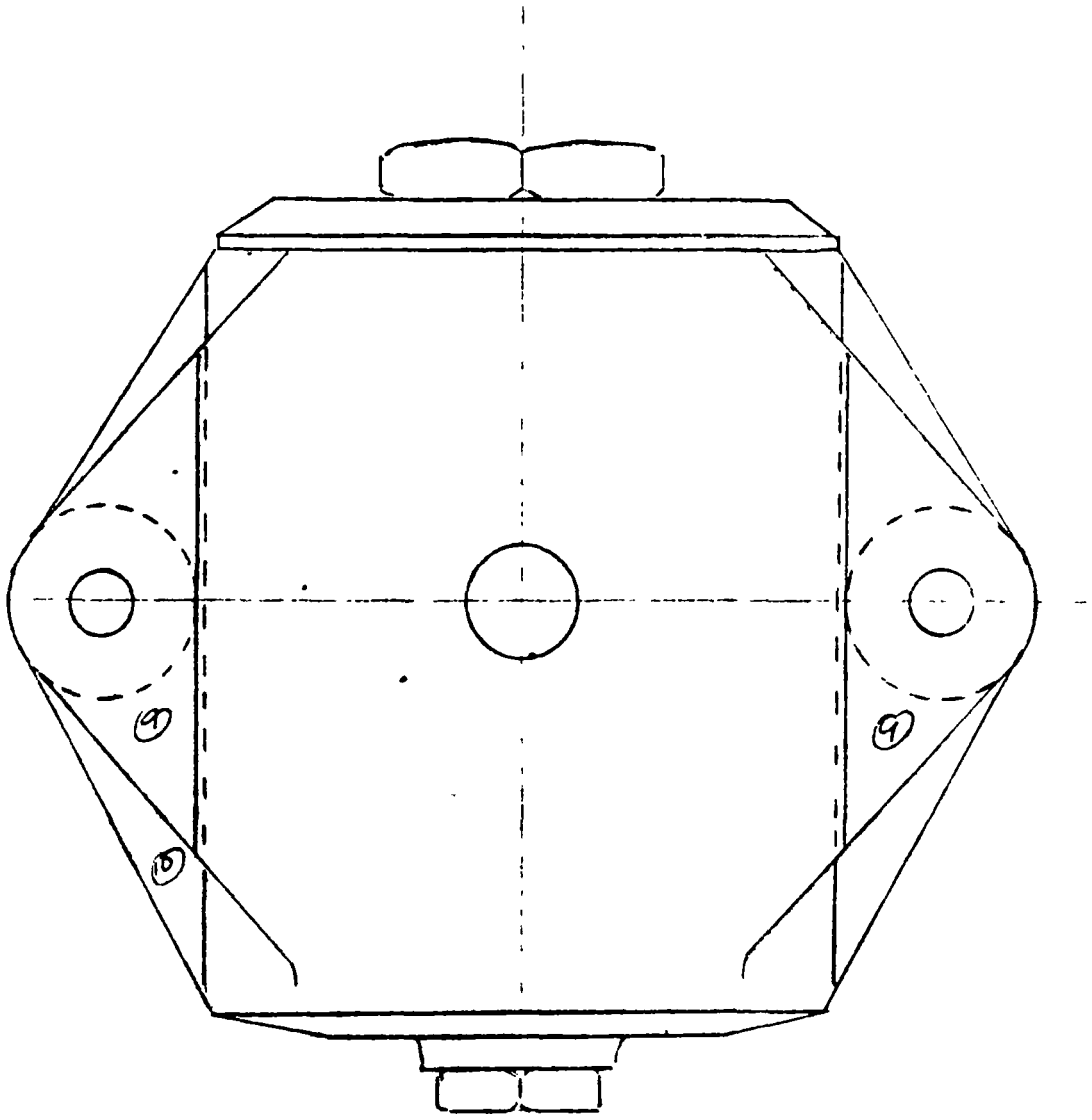
DRWG NO 254NA86004



A - A

. 1/2 SCALE

DRWG NO 25UAA8600V



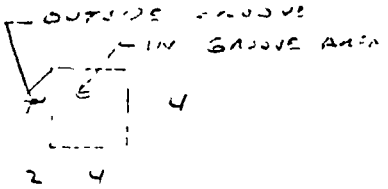
E-E

½ SCALE

AFT SKIRT SECTION

- VTT STAGE SEPARATION
DRW NO 25M30004

RAM LOCKING LOCK



$V_1 = \pi(2.0)^2 \times .175 = 0.70$

$V_2 = .4(.4) \times .08 \times 10 = 1.28$

$V_T = 1.98\ IN^3$

ASSUME MATERIAL STEEL

$WT = 1.98\ IN^3 (.286\ LB/IN^3) = 0.57\ LBS$

ASSUME 0.6 LBS

LOCK PISTON PLATE

$V_1 = .785[(5.7)^2 - (1.5)^2][.5] = 11.4\ IN^3$

$V_2 = (.2)(3) \times 2\pi(1.0) = 0.4\ IN^3$

$V_3 = (.25)(3) \times 2\pi(2.5) = 1.2\ IN^3$

$V_4 = -(.785)(.25)(.75) \times 10 = -1.8\ IN^3$

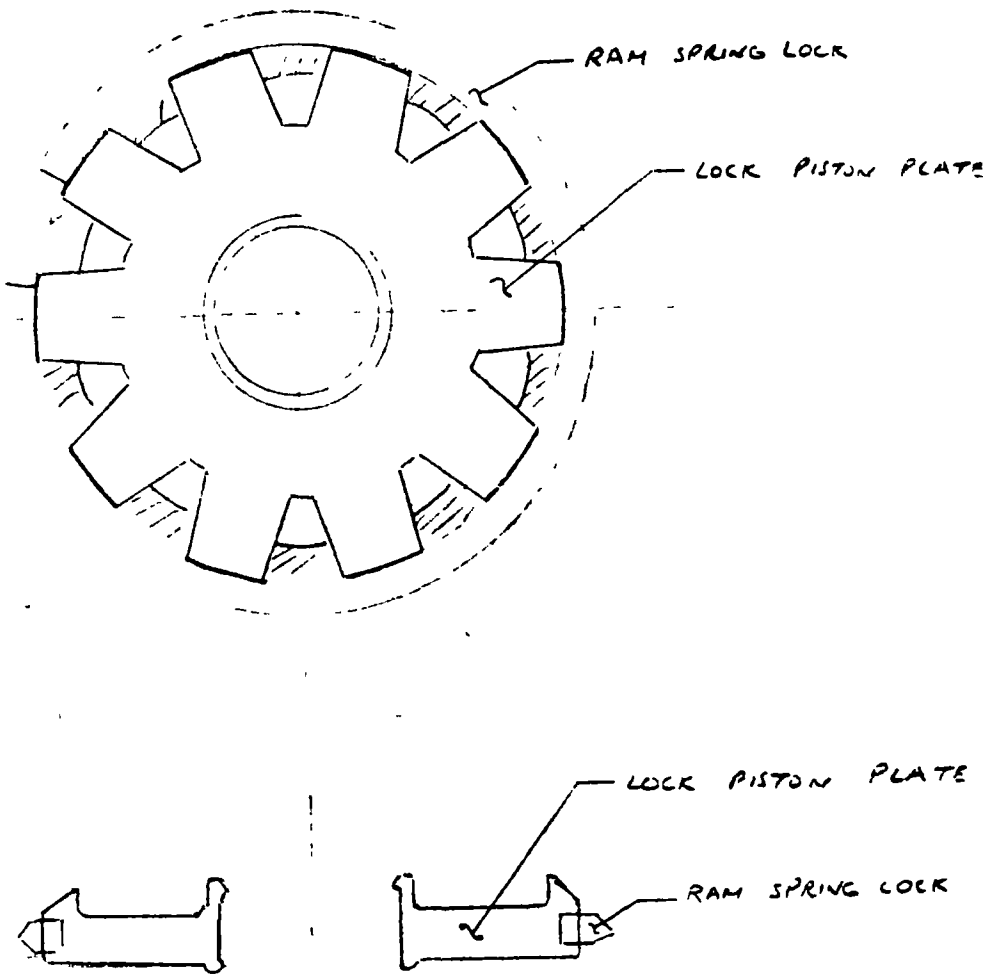
$V_T = 11.2\ IN^3$

ASSUME MATERIAL STEEL

$WT = (11.2\ IN^3)(.286\ LB/IN^3) = 3.2\ LBS$

INTERSTAGE SEPARATION

DRWG NO. 254AA86004



½ SCALE

INTERSTAGE SEPARATION
[illegible] 86004

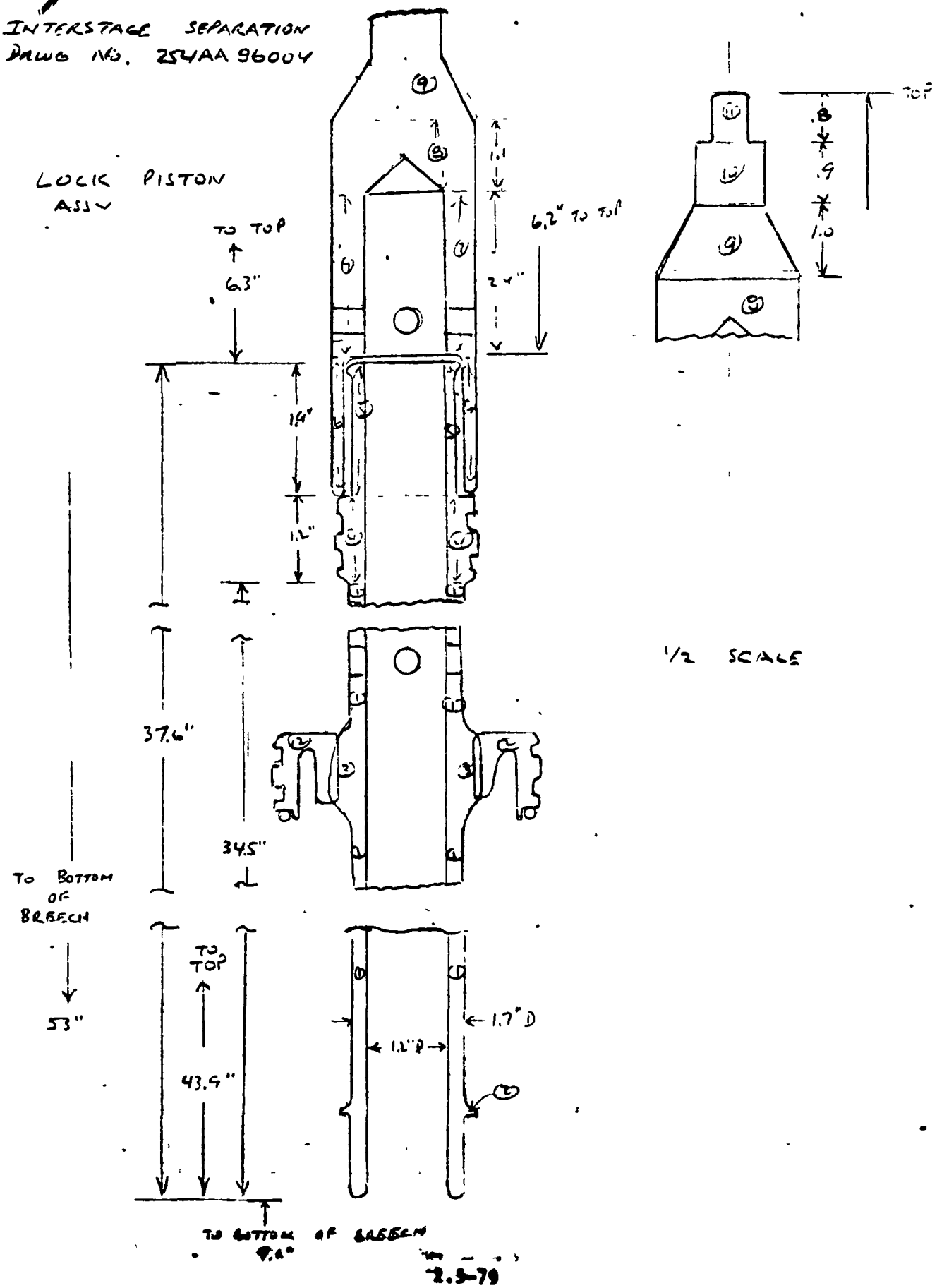
LOCK PISTON ASSY

		VOL (in^3)
$V_1 = .785[(1.7)^2 - (1.2)^2][34.5]$	=	39.3
$V_2 = (.2)(.2) \times 2\pi(1.0)$	=	0.3
$V_3 = (1.2)(.3) \times 2\pi(1.0)$	=	2.3
$V_4 = .785[(2.15)^2 - (1.2)^2][1.2]$	=	3.0
$V_5 = .785[(1.5)^2 - (1.2)^2][1.9]$	=	1.2
$V_6 = .785[(2.15)^2 - (1.75)^2][2.0]$	=	2.5
$V_7 = .785[(2.15)^2 - (1.2)^2][2.4]$	=	6.0
$V_8 = .785(2.15)^2(1.1) - \frac{1}{3}\pi(.6)^2(.5)$	=	3.8
$V_9 = \frac{1}{3}\pi(1.0)[(1.08)^2 + (1.08)(.53) + (.53)^2]$	=	2.2
$V_{10} = .785(1.05)^2(.9)$	=	0.8
$V_{11} = .785(.55)^2(.8)$	=	0.2
$V_{12} = [(.3)(1.1) + (1.1)(.4) + (.3)(.2)][2\pi(1.75)]$	=	9.1
V_T	=	70.7 in^3

ASSUME MATERIAL STEEL

$WT = (70.7\ in^3)(.286\ lb/in^3) =$ 20.2 LBS

INTERSTAGE SEPARATION
DRWG NO. 25AA 96004



2.5-79

INTERSTAGE SEPARATION

DRWG NO 25YAA96004

LOCK ASSY COMPRESSION SPRING

PER RON RENTEZEL OF ST LOUIS
CONSIDER SPRING 3.5" SOLID HEIGHT
& 0.2" DIAMETER

$V = .785(.2)^2 \times \pi(3.75) \times 3.5 = 1.3\ IN^3$

ASSUME MATERIAL STEEL

$WT = (1.3\ IN^3 \times .286\ LB/IN^3) = \underline{0.4\ LB}$

RAM RETURN SPRING

PER RON RENTEZEL OF ST LOUIS
CONSIDER SPRING 9.0" SOLID HEIGHT

$V = (.35 \times .35) - \pi(5.4) \times 9.0 = 18.7\ IN^3$

ASSUME MATERIAL STEEL

$WT = (18.7\ IN^3 \times .286\ LB/IN^3) = \underline{5.4\ LBS}$

INTERSTAGE SEPARATION
DRWG NO 254AA86004

RAM ASSY

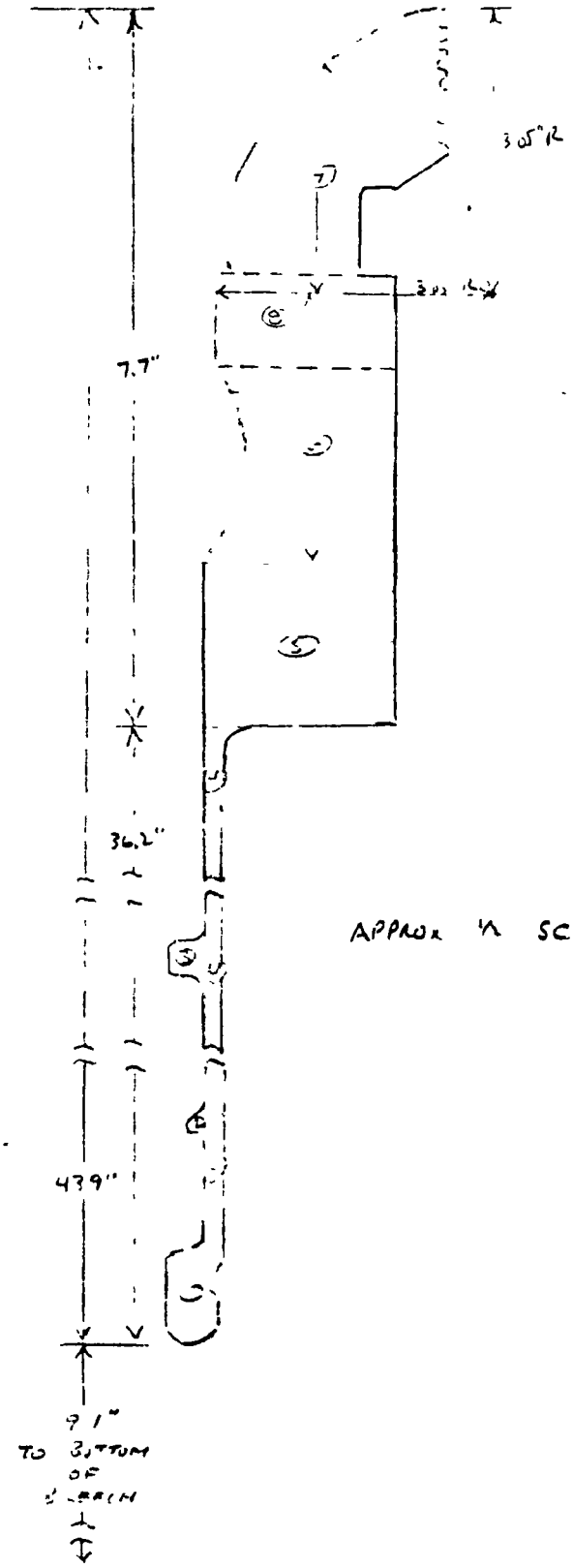
			VOL (IN^3)
V_1 =	$[(.65)(1.05) - \frac{1}{2}(.2)(.2)\times 2 - \frac{1}{2}(.2)(.2)\times 2][2\pi(3.4)]$	=	12.88
V_2 =	$[(.2)(.2\pi)][2\pi(3.3)]$	=	1.04
V_3 =	$[(.4)(.3\pi)][2\pi(3.4)]$	=	2.99
V_4 =	$[(35.2)(25) + .2146(.39)^2][2\pi(3.1)]$	=	172.00
V_5 =	$[(1.7\pi)(2.1)][2\pi(2.1)]$	=	48.50
V_6 =	$[(2.9)(1.95)][2\pi(2.0)]$	=	67.50
V_7 =	$\frac{1}{2}\times\frac{4}{3}\pi(3.05)^3 - .78\pi(1.0)^2(1.7)$ $- \frac{1}{2}\pi(.3)[(1.05)^2 + (1.05)(.5) + (.5)^2]$ $- .78\pi(2.9)^2(.95) - .78\pi(2.1)^2(.2)$	=	51.20
V_8 =	$-(1.9)(1.0)(2.0)\times 4$	=	- 15.20
		V_T =	340.91 IN^3

ASSUME MATERIAL STEEL.

$WT = (340.91\ IN^3)(.286\ LB/IN^3)$ = 97.5 LBS

INTERSTAGE SEPARATION
DRWG NO 25YAA96004

RAM ASSY



APPROX ¼ SCALE

INTERSTAGE SEPARATION
DRWG NO. 25VAA86004

HOUSING ASSY NO. 1

$V_1 = [(.5)(.25)][2\pi(4.2)] = 3.3 \ IN^3$

$V_2 = [(.65)(.2)][2\pi(3.9)] = 3.2 \ IN^3$

$V_3 = [(34.2)(.25)][2\pi(3.7)] = 199.0 \ IN^3$

$V_4 = [(2.0)(.35)][2\pi(3.8)] = 16.7 \ IN^3$

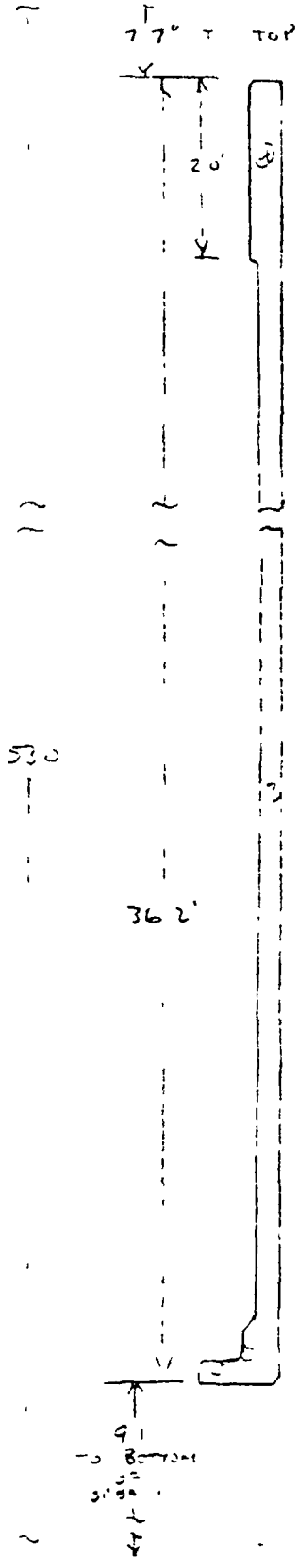
$V_T = 222.2 \ IN^3$

ASSUME MATERIAL STEEL

$WT = (222.2 \ IN^3)(.286 \ LB/IN^3) = 63.6 \ LBS$

INTERSTAGE SEPARATION
DRUG NO. 25VAR 8L004

HOUSING ASSY NO 1



APPROX ½ SCALE

INTERSTAGE SEPARATION
DRWG No 254AA96001V

HOUSING ASSY No. 2

$V_1 = \pi(.3+.9)(.9)(3.6) \times 10 = 17.8\ IN^3$
$V_2 = [(2\pi 19][2\pi(3.0)] = 9.0\ IN^3$
$V_3 = [(.15)(.4\pi)][2\pi(2.9)] = 1.2\ IN^3$
$V_4 = [(.5)(.3)][2\pi(3.25)] = 3.1\ IN^3$
$V_5 = [(2.5)(.15)][2\pi(2.9)] = 3.4\ IN^3$
$V_6 = [(.4)(.25)][2\pi(2.3)] = 5.1\ IN^3$
$V_7 = [(.3)(.4.5)][2\pi(3.4)] = 5.0\ IN^3$
$V_8 = [(27.8)(.25)][2\pi(2.0)] = 91.8\ IN^3$
$V_9 = [(.24)(.25)][2\pi(2.25)] = 8.5\ IN^3$
$V_{10} = [(.5)(.2)][2\pi(2.05)] = 1.3\ IN^3$

$V_T = 146.2\ IN^3$

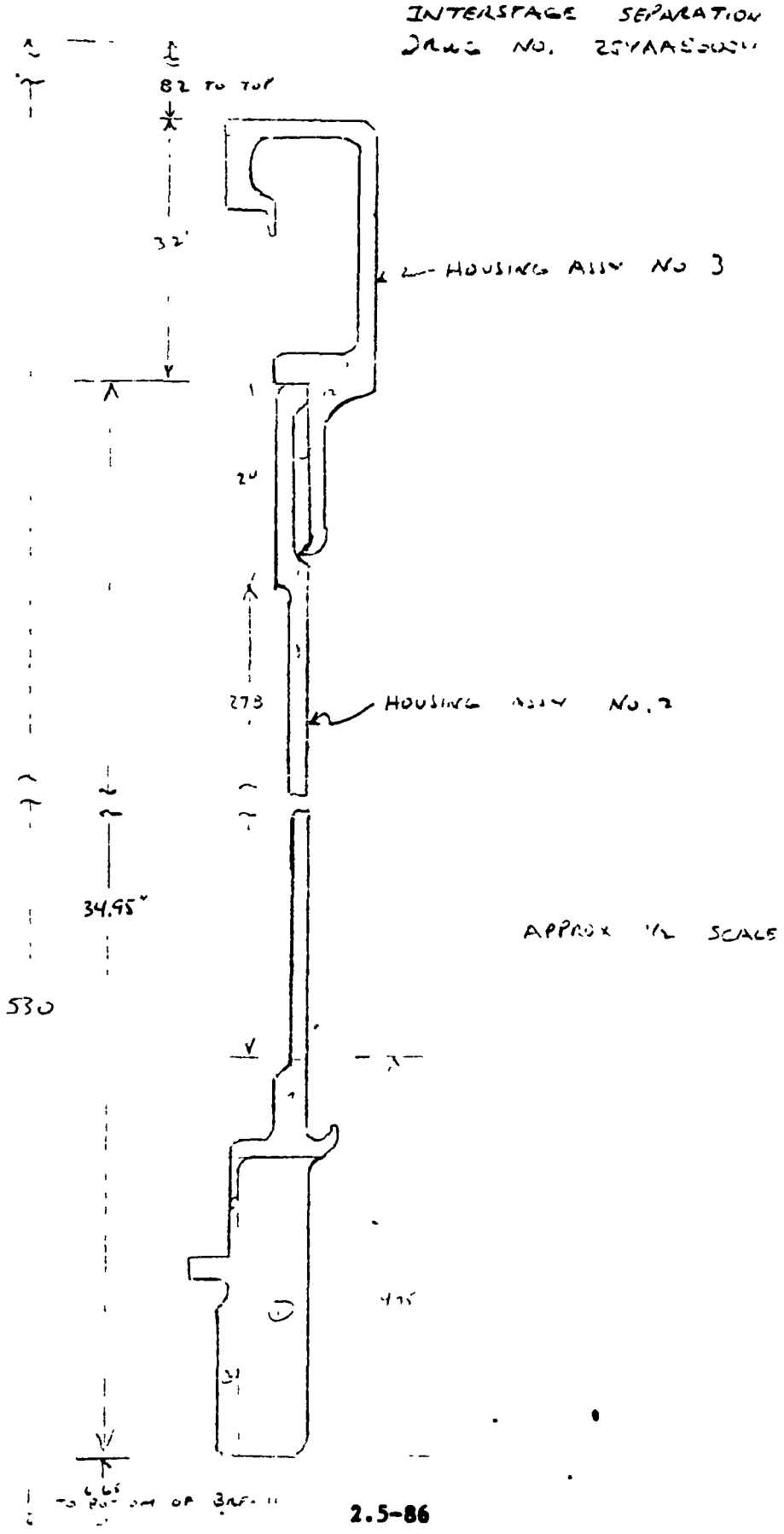
ASSUME MATERIAL STEEL
$WT = (146.2\ IN^3)(.286\ LB/IN^3) = \underline{41.8\ LBS}$

HOUSING ASSY No. 3

$V_{11} = [(.4)(1.75)][2\pi(1.95)] = 8.6\ IN^3$
$V_{12} = [(.35)(.3)+(.65)(.2)][2\pi(1.7)] = 2.5\ IN^3$
$V_{13} = [(.3)(.4)][2\pi(1.7)] = 5.6\ IN^3$
$V_{14} = [(2.8)(.25)][2\pi(1.2)] = 5.3\ IN^3$
$V_{15} = [(1.65)(.2)][2\pi(2.1)] = 4.4\ IN^3$
$V_{16} = [(.3)(.9)+(.3)(.15)+(.3)(.1)][2\pi(2.6)] = 5.7\ IN^3$

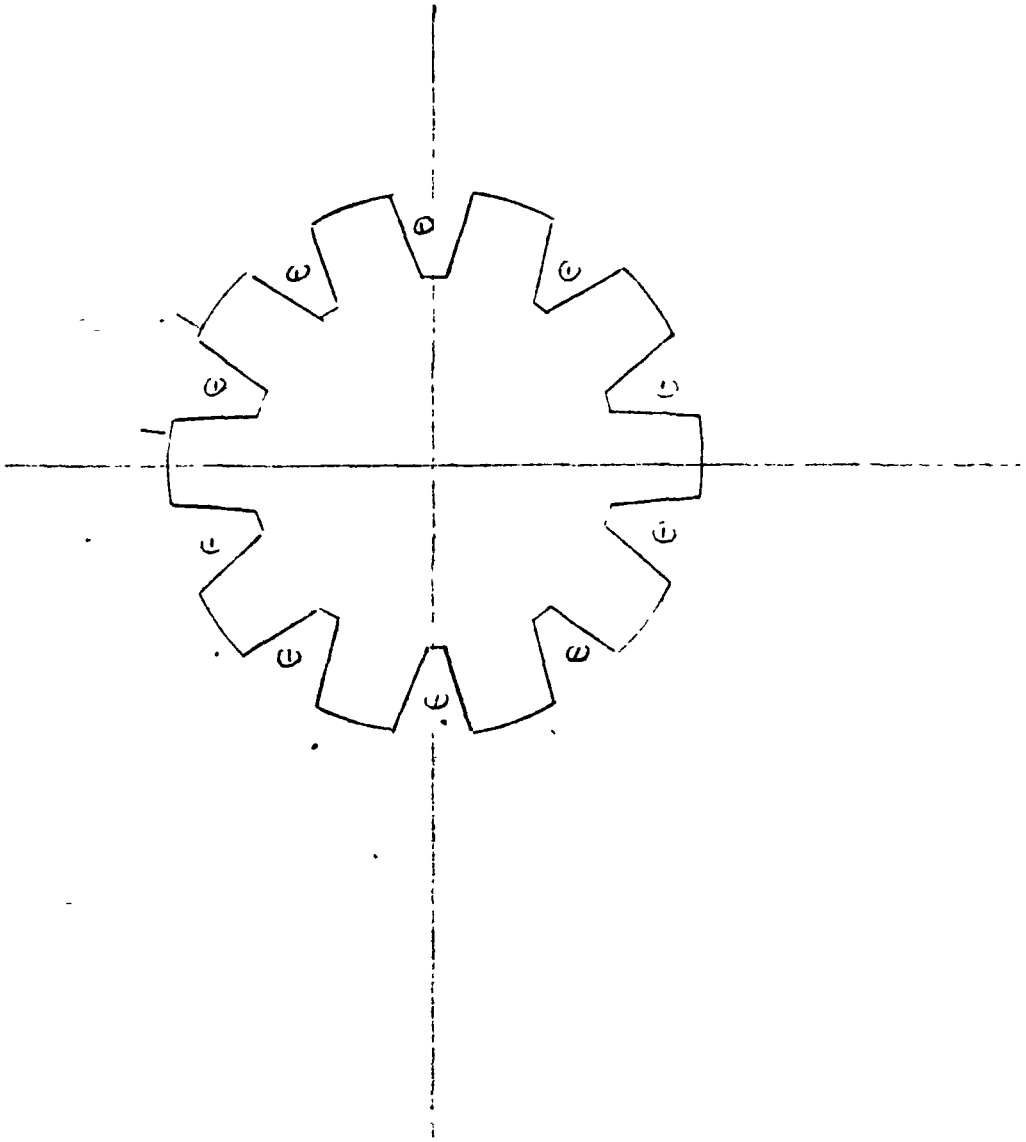
$V_T = 32.1\ IN^3$

ASSUME MATERIAL STEEL
$WT = (32.1\ IN^3)(.286\ LB/IN^3) = \underline{9.2\ LBS}$


INTERSTAGE SEPARATION
82 TO TOP
32"
HOUSING ASSY NO 3
20"
27.3
HOUSING ASSY NO. 2
34.95"
530
APPROX 1/2 SCALE

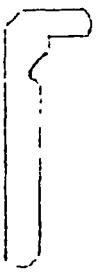
INTERSTAGE SEPARATION
DRWG No. 254AA96004

HOUSING ASSY No. 2



[illegible] STAGE SEPARATION
[illegible] STA 3600

HOUSING ASSY NO 4



APPROX ½ SCALE

$V = [(.4)(2.5) + (.45)(.5) - (.4)(.25)][2\pi(4.75)] = 35.4\ in^3$

ASSUME MATERIAL STEEL

$WT = 35.4\ in^3 (.286\ LB/in^3) =$ 10.1 LBS

INTERSTAGE SEPARATION
DRWG NO. 254AA86004

DOGS 4 REQ

$V = [(2.0)(1.0) + 2(.2+1.0)(.6)][20]$

$V = 4.72 \text{ IN}^3$

ASSUME MATERIAL STEEL

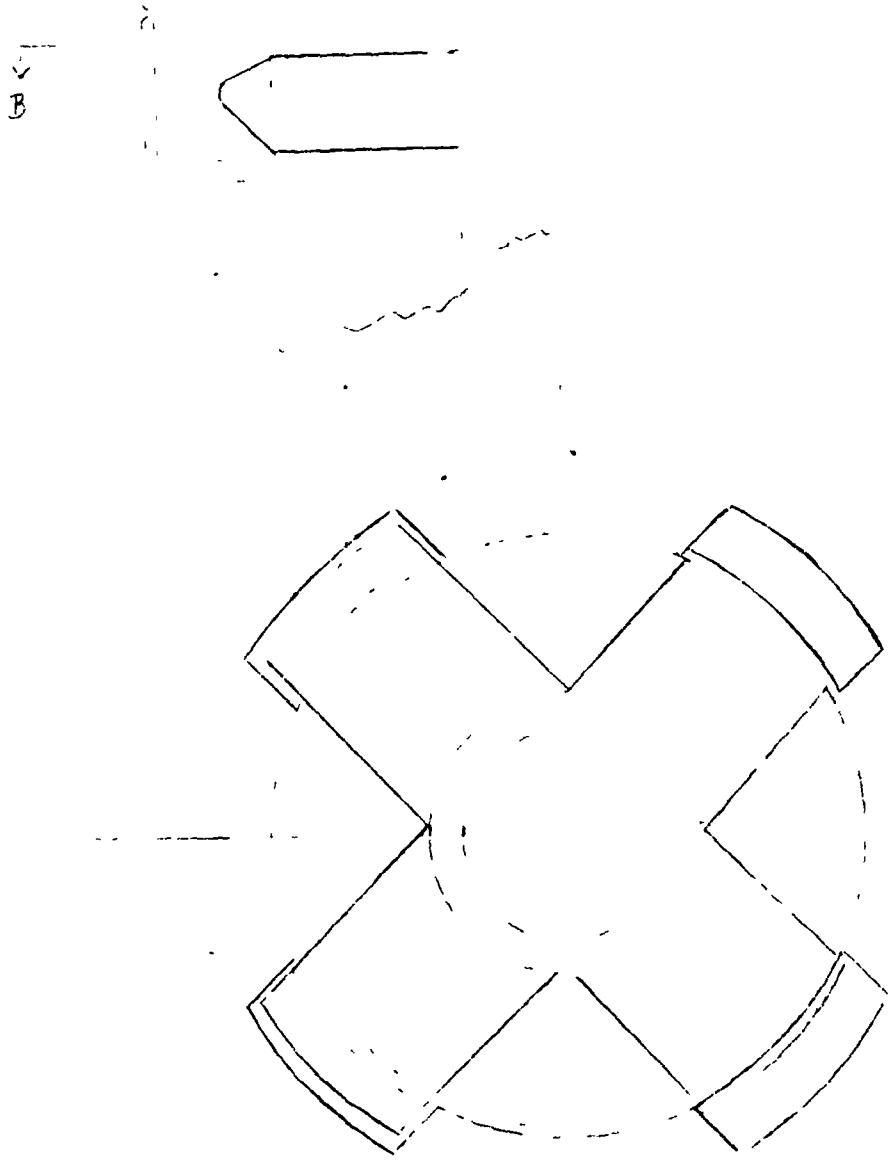
$WT = (4.72 \text{ IN}^3)(.286 \text{ LBS/IN}^3)$

WT/EA = 1.3 LBS

WT/4 = 1.3 × 4 = 5.2 LBS

Drwg No 254AA80004

Does



INTERSTAGE SEPARATION

DRWG NO. 254AA96004

MISC

APPROX 1/2 SCALE

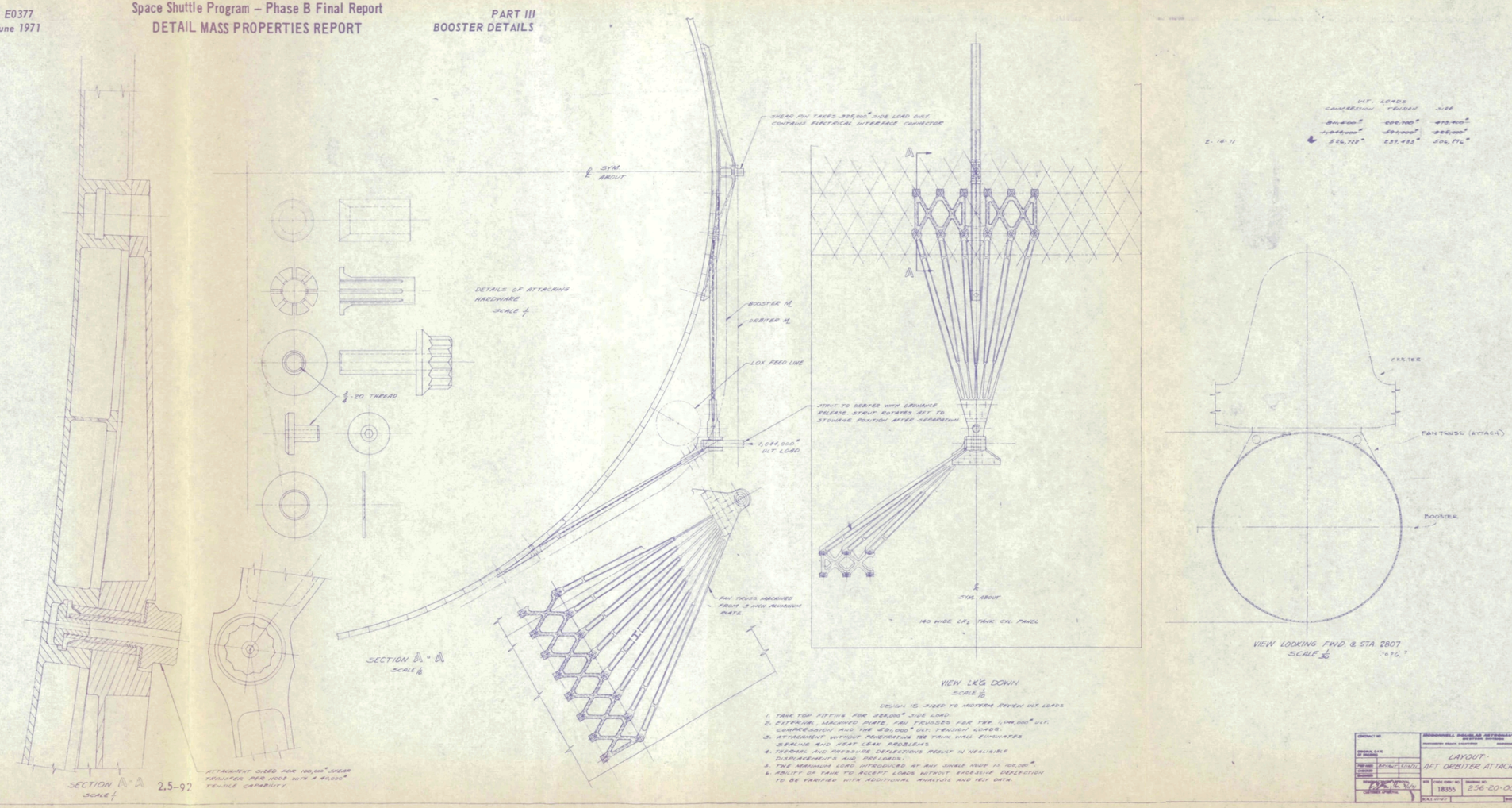
$V_1 = [(.5 + .35[.05)]\ [2\pi(2.5)] = 0.7\ IN^3$

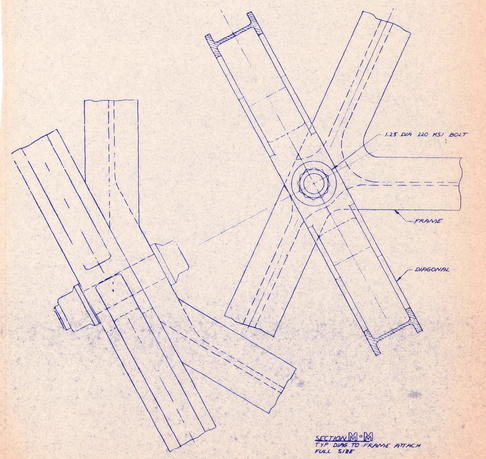
$V_L = [(2.45[.15)]\ 2\pi(2.81)] = 6.5\ IN^3$

$V_T = 7.2\ IN^3$

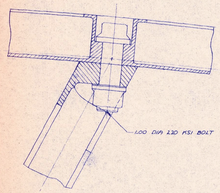
ASSUME MATERIAL STEEL

$WT = (7.2\ IN^3 \times .286\ LB/IN^3) = \underline{2.1\ LBS}$

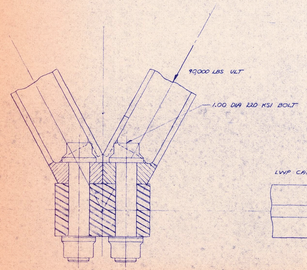

SECTION A-A
SCALE 1/1
ATTACHMENT SIZED FOR 100,000# SHEAR TRANSFER PER NODE WITH A 40,000# TENSILE CAPABILITY.
DETAILS OF ATTACHING HARDWARE
SCALE 1/1
3/4-20 THREAD
SECTION A-A
SCALE 1/10
℄ SYM. ABOUT
SHEAR PIN TAKES 325,000# SIDE LOAD ONLY. CONTAINS ELECTRICAL INTERFACE CONNECTOR
BOOSTER ML
ORBITER ML
LOX FEED LINE
STRUT TO ORBITER WITH ORDNANCE RELEASE. STRUT ROTATES AFT TO STOWAGE POSITION AFTER SEPARATION
1,044,000# ULT. LOAD
FAN TRUSS MACHINED FROM 3 INCH ALUMINUM PLATE.
℄ STA. ABOUT
140 WIDE LF2 TANK CYL. PANEL
VIEW LK'G DOWN
SCALE 1/10
ULT. LOADS
COMPRESSION TENSION SIDE
2-14-71
526,728# 237,483# 506,276#
ORBITER
FAN TRUSS (ATTACH)
BOOSTER
VIEW LOOKING FWD. @ STA. 2807
SCALE 1/30
DESIGN IS SIZED TO MIDTERM REVIEW ULT. LOADS
1. TANK TOP FITTING FOR 325,000# SIDE LOAD.
2. EXTERNAL, MACHINED PLATE, FAN TRUSSES FOR THE 1,044,000# ULT. COMPRESSION AND THE 491,000# ULT. TENSION LOADS.
3. ATTACHMENT WITHOUT PENETRATING THE TANK WALL ELIMINATES SEALING AND HEAT LEAK PROBLEMS.
4. THERMAL AND PRESSURE DEFLECTIONS RESULT IN NEGLIGIBLE DISPLACEMENTS AND PRELOADS.
5. THE MAXIMUM LOAD INTRODUCED AT ANY SINGLE NODE IS 100,000#.
6. ABILITY OF TANK TO ACCEPT LOADS WITHOUT EXCESSIVE DEFLECTION TO BE VARIFIED WITH ADDITIONAL ANALYSIS AND TEST DATA.
LAYOUT - AFT ORBITER ATTACHMENT
18355
256-20-0006

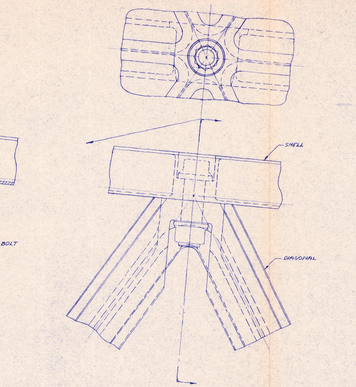


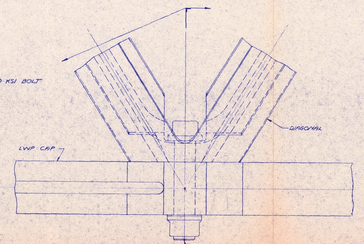
SECTION M-M
TYP DIAG TO FRAME ATTACH
FULL SIZE



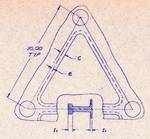
SECTION L-L
TYP DIAG TO SHELL ATTACH
FULL SIZE







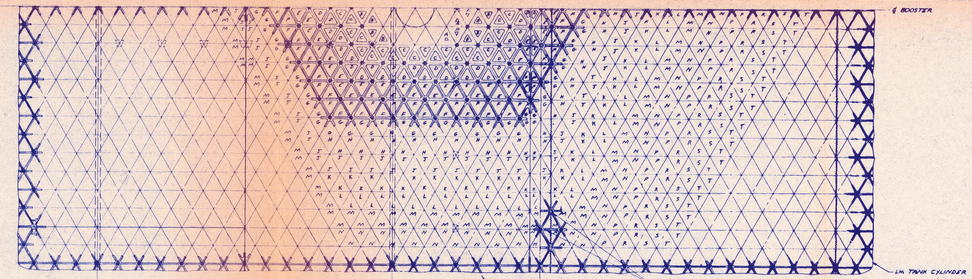
DET M
TYP DIAG TO LWA CAP ATTACH
FULL SIZE



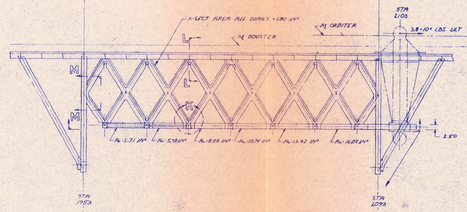
POCKET DIMS & FWD GIRDER ATTACH

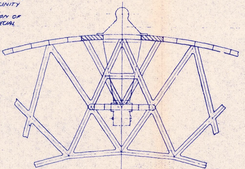
POCKET	STA LOCATION	t_1	t_2	C	t_4
A	1,400	.338	1.370	*	*
B	1,900	.295	.680	*	*
C	13,300	.240	1.370	*	*
D	17,800	.187	.850	*	*
E	25,200	.193	.370	*	*
F	27,100	.214	.923	1.700	.760
G	29,900	.193	.198	.700	.257
H	31,400	.172	.241	.600	.257
I	34,000	.172	.241	.600	.257
K	37,000	.172	.241	.575	.364
L	41,100	.170	.142	.900	.330
M	47,100	.168	.118	.575	.336
N	50,800	.147	.100	.300	.317
P	51,400	.147	.089	.300	.317
R	51,900	.193	.078	.300	.283
S	54,400	.190	.062	.305	.227
T	57,000	.339	.059	.300	.230

* UNFLARED END



VIEW LOOKING DOWN ON FLAT PATTERN OF SHELL SHOWING DISTRIBUTION OF MATERIAL IN VICINITY OF FWD GIRDER ATTACH
THIS DISTRIBUTION INDICATES THAT RELOCATION OF ATTACH ARRAY .100 IN FWD MAY KEEP SPECIAL MACHINING OUT OF TANK AREAS





SECTION R-R
SCALE 1:0

LAYOUT
INTERTANK STRUCTURE

6. MAIN ASCENT PROPULSION [123320]

ENGINE & ACCESSORIES [98241]		WEIGHT (LB)	PAGE NO.
ENGINES		(89940)	2.6-5
GIMBAL SYSTEM		(5516)	2.6-6
ACTUATORS		4488	2.6-7
PLUMBING		909	2.6-7
CONTROL WIRING		119	2.6-7
CHILL DOWN SYSTEM		(632)	2.6-8
LO_2 PUMPS		37	2.6-13
LO_2 DUCTS, VALVES & BELLOWS		197	2.6-14
LO_2 SUPPORTS & MISC.		8	2.6-13
LH_2 PUMPS		75	2.6-11
LH_2 DUCTS, VALVES & BELLOWS		200	2.6-12
LH_2 SUPPORTS & MISC.		19	2.6-11
LH_2 DUCT VACUUM JACKET		96	2.6-12
PNEUMATIC SYSTEM		(2129)	2.6-16
HELIUM BOTTLES (DRY)		960	2.6-16
BOTTLE JACKETS & SUPPORTS		188	2.6-16
PLUMBING		685	2.6-21
PLENUMS		100	2.6-18
SUPPORTS, CONTROLS & MISC.		196	2.6-18
HYDRAULIC ENGINE CONTROL		(24)	
PROPELLANT SYSTEM [24579]	LH_2	LO_2	2.6-25
FILL, DRAIN & DUMP	(801)	(690)	
LINES	166	77	2.6-36/36
VALVES & FLANGES	362	362	2.6-34/34
BELLOWS	56	56	2.6-34/34
DISCONNECT	15	15	2.6-34/34
DUMP VENT	42	42	2.6-37/37
SUPPORTS & MISC	160	138	2.6-34/34

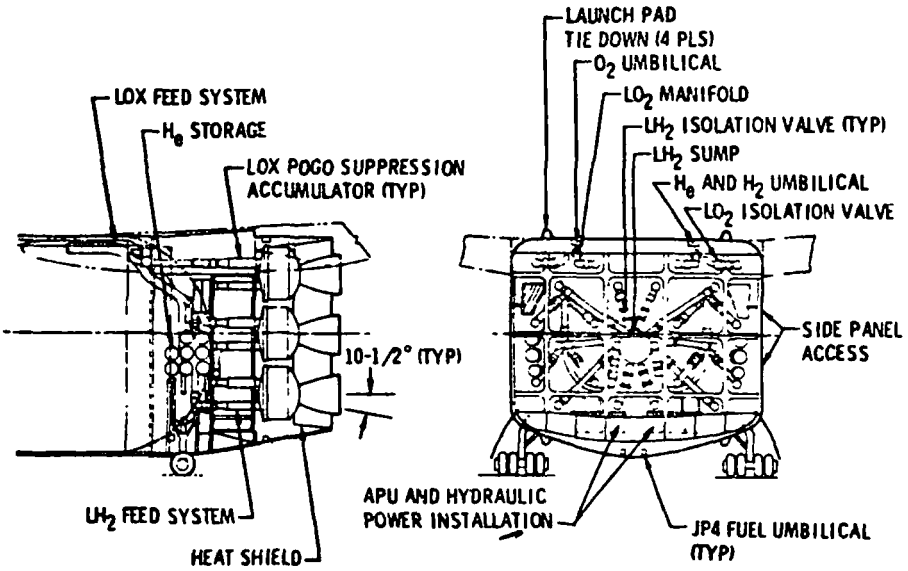
(CONTINUED)

(MAIN ASCENT PROPULSION-CONTINUED)

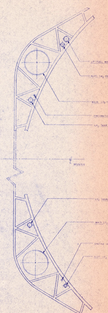
ITEM	LH_2	LO_2	PAGE NO.
PRESSURIZATION & VENT	(1559)	(1732)	2.6-45/39
PRESSURIZATION LINES	397	577	2.6-45/41
VALVES & FLANGES	523	523	2.6-45/39
MANIFOLD	61	61	2.6-47/41
GROUND PRESS. & CHECKOUT	7	7	2.6-47/41
VENT DUCT ASSY	222	181	2.6-48/44
DIFFUSSER ASSY	37	37	2.6-48/44
SUPPORTS & MISC.	312	346	2.6-45/39
PROPELLANT LOADING	(40)	(35)	2.6-49
CAPACITANCE PROBE	20	15	2.6-49
POINT LEVEL SENSORS	1	2	2.6-49
ELECTRONICS PACKAGE	3	3	2.6-49
SUPPORT	5	4	2.6-49
WIRING	11	11	2.6-49
FEED SYSTEM	(6031)	(13691)	2.6-50
DUCTS	860	5861	2.6-52
GIMBAL BELLOWS	1062	2884	2.6-53
ISOLATION VALVES	1740	1740	2.6-53
FLANGES	468	468	2.6-53
DUCT INSULATION JACKET	695	0	2.6-62
SUPPORTS & MISC.	1206	2738	2.6-50
CONTINGENCY	[500]		

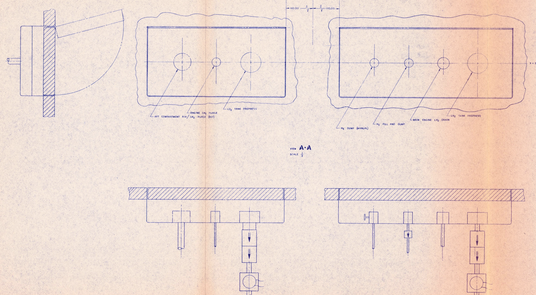
SHUTTLE BOOSTER 371-20157

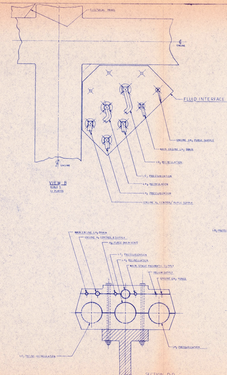
MAIN PROPULSION SYSTEM

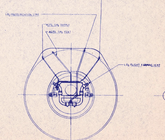


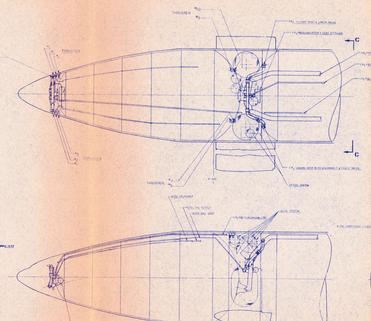
6. PROPULSION – MAIN ASCENT				123320
ENGINE & ACCESSORIES				98241
ENGINE (AS SUPPLIED)			89940	
GIMBAL SYSTEM			5516	
CHILLDOWN SYSTEM			632	
PNEUMATIC SYSTEM			2129	
HYDAULIC ENGINE CONTROL			24	
INSTALLATION, DUCTS, SHROUDS				0
PROPELLANT SY		FUEL	OXIDIZER	24577
FILL DRAIN & DUMP		801	690	
PRESSURIZATION & VENT		1559	1732	
VENT SY		—	—	
PCV SY		0	0	
PROPELLANT LOADING		40	35	
FEED SYSTEMS		6031	13691	
CONTINGENCY				500
TANKAGE – NONINTEGRAL	TANK	INSULATE	SUPTS	0
FUEL				
OXIDIZER				

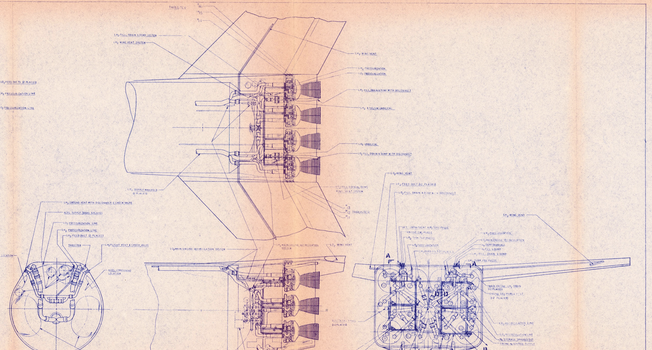












ASCENT PROPULSION ENGINES

LOX ENGINE WEIGHT (INCL. 55# FOR RING TO SUPPORT TPS)	7495# EACH
12 ENGINES	89,940# TOTAL

ENGINE CHARACTERISTICS

CHAMBER PRESSURE	3000 PSI
EXPANSION RATIO	35:1
VACUUM SPECIFIC IMPULSE	439±3 SEC
SEA LEVEL THRUST	550,000 LB
VACUUM THRUST	604,000 LB

GIMBAL SYSTEM

ACTUATORS (24 @ 187#)	4488
LINES, FITTINGS & INSTALLATION	909
SUPPORTS & INSTALLATION	*
CONTROL WIRING	119
TOTAL	5516

* CHARGED TO THRUST STRUCTURE

GIMBAL SYSTEM

CONTROL WIRING

ASSUME 4 LB PER 1000' OF WIRING, CONNECTORS AND INSTALLATION. ASSUME 1.3 ROUTING FACTOR.

14 SIGNALS PER CHANNEL
4 CHANNELS PER SECONDARY ACTUATOR
1 SECONDARY ACTUATOR PER POWER ACTUATOR
24 POWER ACTUATORS
17 FT AVERAGE WIRE LENGTH (INCL. ROUTING FACTOR)

$$\text{WEIGHT} = \frac{4\#}{1000'} \times 14 \times 4 \times 24 \times 17' \times 1.3 = \underline{119\#}$$

ACTUATORS AND LINES, FITTINGS & INSTALLATION

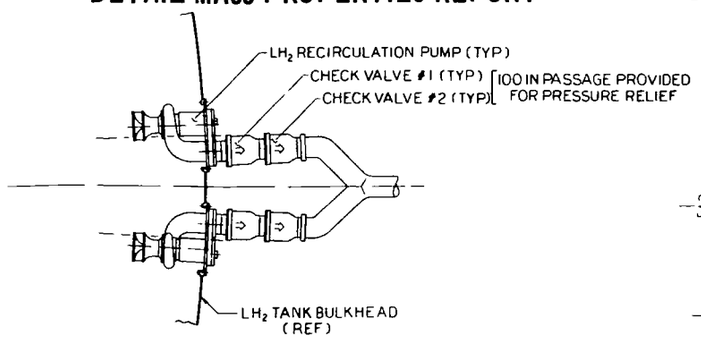
DUE TO THE INTERRELATIONSHIP OF THE GIMBAL SYSTEM AND THE HYDRAULIC SYSTEM, THE ACTUATORS AND THE INSTALLED MISC. FITTINGS WEIGHTS ARE DETERMINED IN SECTION 2.11-31

CHILLDOWN SYSTEM

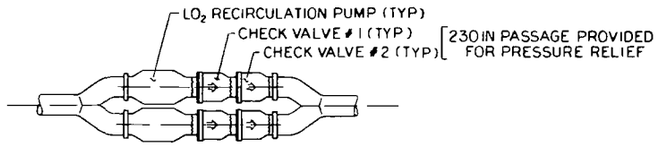
	WEIGHT (LB)
HYDROGEN SYSTEM	(390)
LINES	156
BELLOWS	95
FITTINGS	31
CLAMPS	19
PUMP	75
VALVES, CHECK	14
OXYGEN SYSTEM	(242)
LINES	67
BELLOWS	102
FITTINGS	14
CLAMPS	8
PUMP	37
VALVES, CHECK	14
TOTAL (DRY)	632

Space Shuttle Program – Phase B Final Report
DETAIL MASS PROPERTIES REPORT

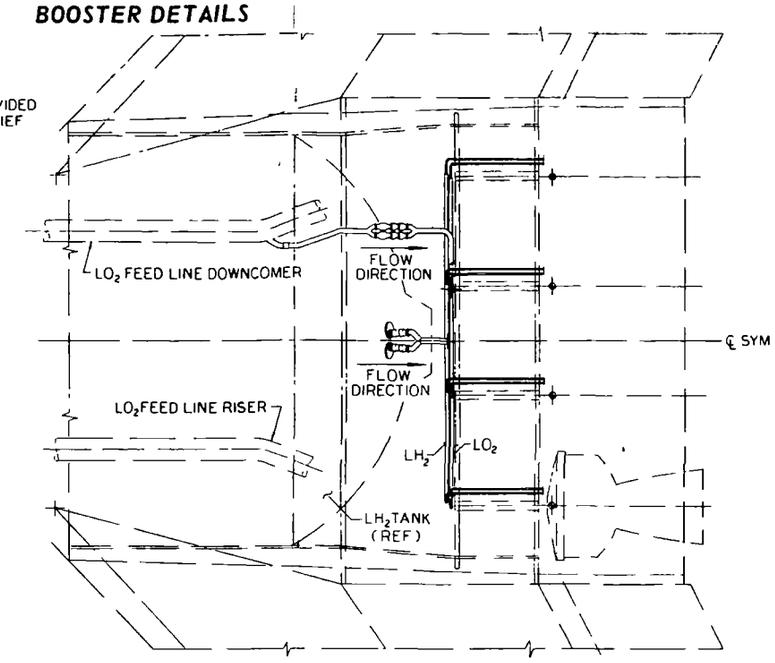
PART III
BOOSTER DETAILS



SECTION C-C
SCALE 1/10



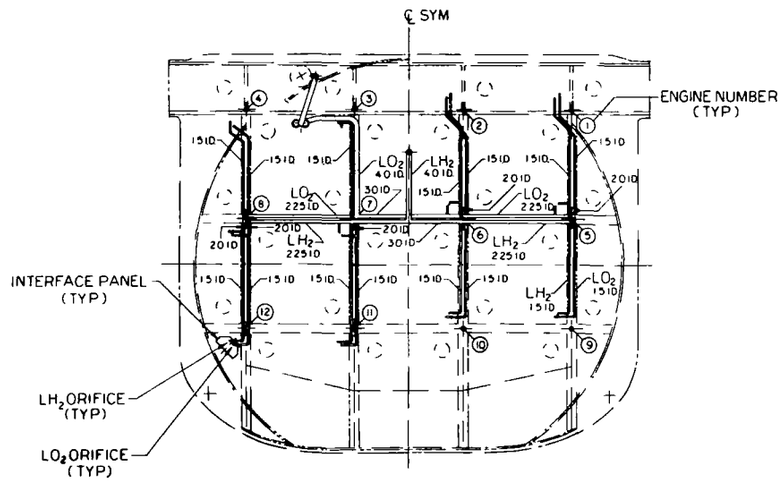
SECTION B-B
SCALE 1/10



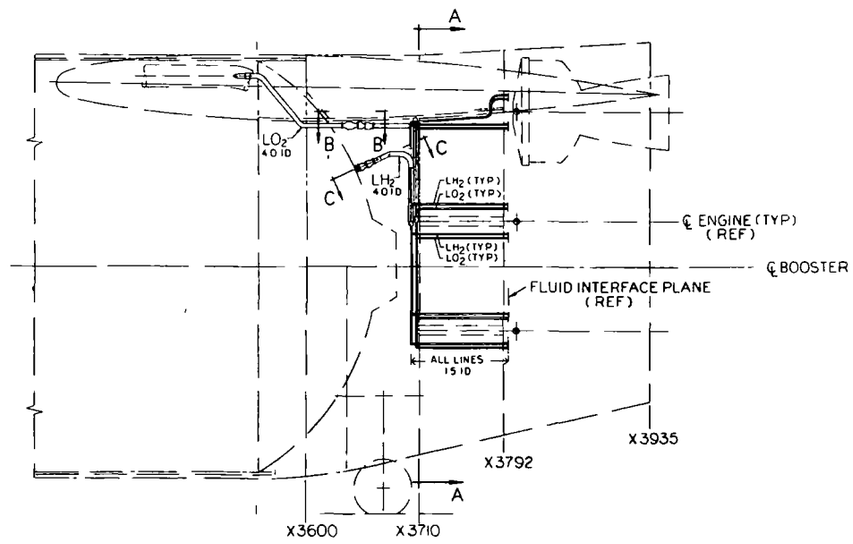
PLAN VIEW
SCALE 1/50

ORIFICE SIZES

ENGINE	LO_2	LH_2
1	1.112	1.184
2	1.080	1.142
3	1.156	1.137
4	1.026	1.102
5	NONE	NONE
6	1.259	1.246
7	1.195	1.347
8	1.045	1.325
9	1.334	1.320
10	1.205	1.209
11	1.162	1.276
12	1.029	1.255



SECTION A-A
LOOKING AFT
SCALE 1/50



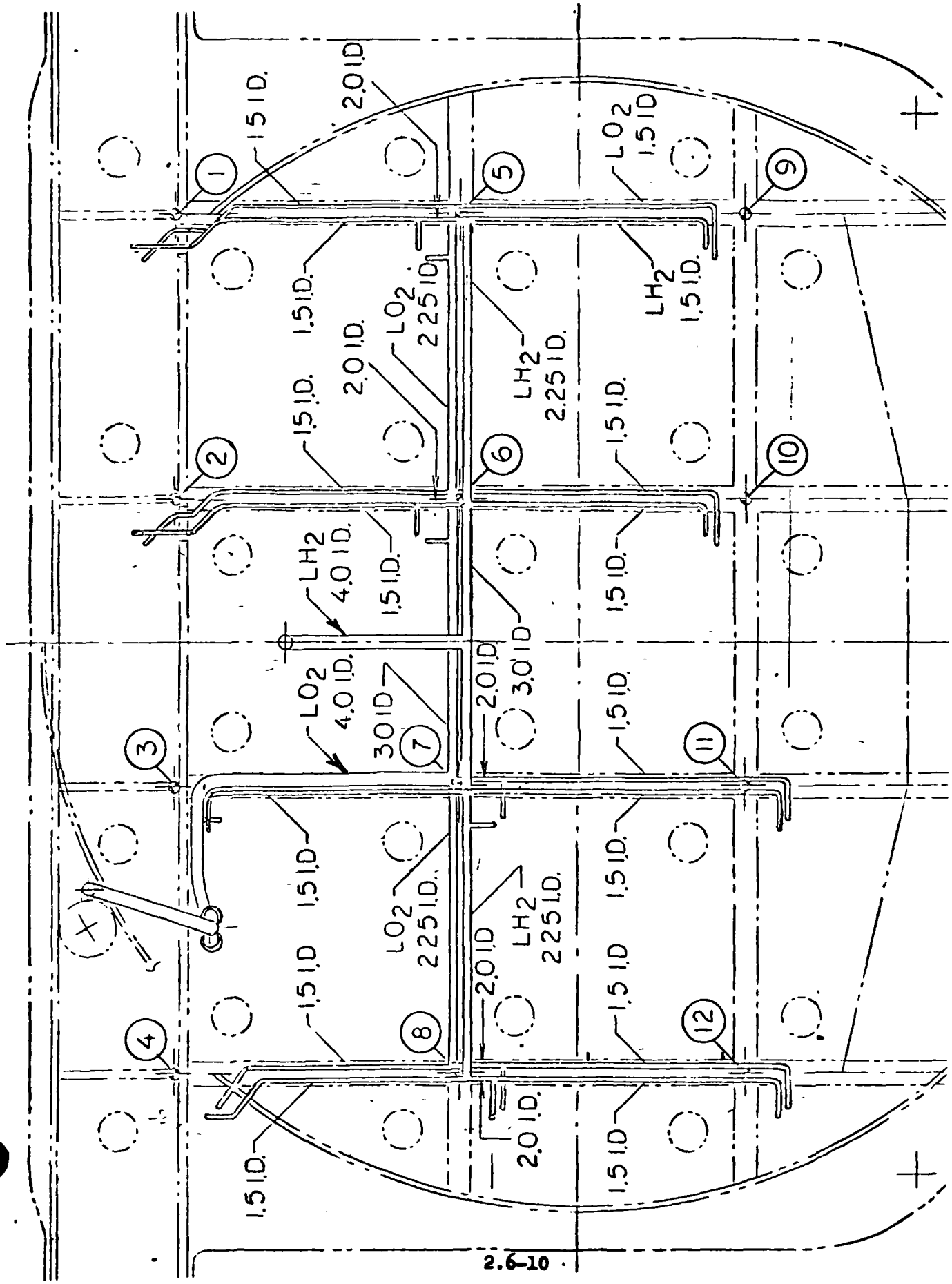
SIDE VIEW
SCALE 1/50

M G WINTER 5/13/71

BOOSTER-MAIN ENGINE RECIRCULATION SYSTEM

899A2020640

NOTED


1.51 I.D.
2.01 I.D.
LO2 1.51 I.D.
1.51 I.D.
2.01 I.D.
LO2 2.25 I.D.
LH2 2.25 I.D.
LH2 1.51 I.D.
1.51 I.D.
1.51 I.D.
LH2 4.01 I.D.
1.51 I.D.
1.51 I.D.
LO2 4.01 I.D.
3.01 I.D.
3.01 I.D.
2.01 I.D.
1.51 I.D.
1.51 I.D.
1.51 I.D.
LO2 2.25 I.D.
LH2 2.25 I.D.
2.01 I.D.
1.51 I.D.
1.51 I.D.
2.01 I.D.
1.51 I.D.
1.51 I.D.
1
2
3
4
5
6
7
8
9
10
11
12
END VIEW

HYDROGEN SYSTEM SUMMARY

LINES	156.3
BELLOWS	94.8
FITTINGS 20% OF LINES	31.3
CLAMPS 10% OF LINES & FITTINGS	18.4
PUMP 2 REQ PESCO CO DATA	75.0
VALVES, CHECK 4 REQ	14.0
TOTAL	390.2 LB

HYDROGEN LINES

50 PSI MAX PRESS S.F. ULT = 2 MIN GAGE = .016

LINE NO	WALL t IN	SIZE I.D. IN	UNIT WT LB/IN	LENGTH IN	WT LB
1	.016	1 1/2	.0218	1898	41.4
2	.016	2	.0289	42	1.2
3	.016	2 1/4	.0325	214	7.0
4	.016	3	.0433	105	4.5
5	.016	4	.0577	105	6.1
				TOTAL	60.2

VACUUM JACKET

.016	2 1/2	.0362	105	3.7
.016	3	.0433	42	1.8
.016	3 1/4	.0469	214	10.0
.016	4	.0577	105	6.1
.020	5	.0902	105	9.5
			TOTAL	96.1
			TOTAL LINES	156.3

HYDROGEN GIMBAL BELLOWS

NO. REQ.	SIZE (IN)	WT (EA)	WT
20	1 1/2	2.5	50.0
4	2	3.7	14.8
2	2 1/4	4.0	8.0
1	3	6.0	6.0
2	4	8.0	16.0
		TOTAL	94.8 LB

94.8 LB

DEN 080037 (3-57)

OXYGEN SYSTEM SUMMARY

LINES	67.5
BELLOWS	101.9
FITTINGS 20% OF LINES	13.5
CLAMPS 10% OF LINES	8.1
PUMP 2 REQ PESCO CO DATA	37.0
VALVES, CHECK 4 REQ	14.0
TOTAL	242 LB

OXYGEN LINES

50 PSI MAX PRESS S.F ULT = 2 MIN GAGE = .016

LINE NO	WALL t IN	SIZE I.D. IN	UNIT WT LB/IN	LENGTH IN	WT LB
1	.016	1½	.0136	1679	36.6
2	.016	2	.0217	30	.9
3	.016	2¼	.0244	200	6.5
4	.016	3	.0433	105	4.5
5	.016	4	.0579	330	19.0
			TOTAL		67.5 LB

OXYGEN GIMBAL BELLOWS

NO REQ	SIZE (IN)	WT (EA)	WT
18	1½	2.8	50.4
4	2	4.5	18.0
2	2¼	5.0	10.0
1	3	6.5	6.5
2	4	8.5	17.0
	TOTAL		101.9 LB

CHILL DOWN TRAPPED PROPELLANT

HYDROGEN

LINE NO	UNIT WT	LENGTH	WT
1	.00450	1878	8.5
2	.00796	42	.3
3	.0101	214	2.2
4	.0179	105	1.9
5	.0319	105	3.3
IN COMPONENTS			.5
	TOTAL		16.7 ~ 20LB

OXYGEN

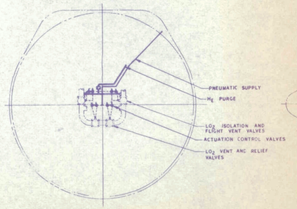
LINE NO	UNIT WT	LENGTH	WT
1	.0725	1679	122.2
2	.129	30	3.9
3	.164	200	32.8
4	.290	105	30.5
5	.519	330	170.6
	TOTAL		360.0 LB

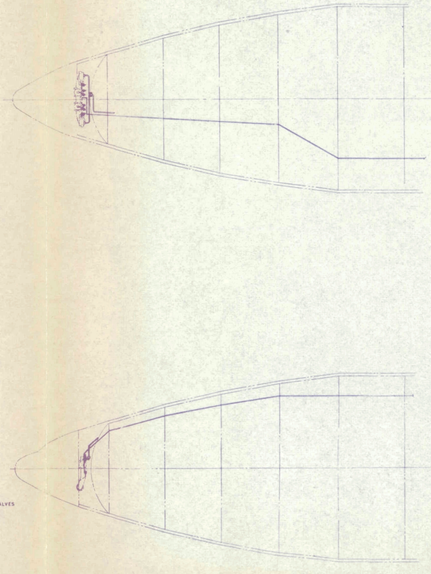
PNEUMATIC SYSTEM

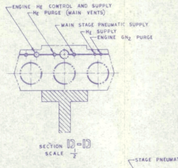
THE HELIUM STORAGE BOTTLES COMPOSE ABOUT ONE HALF OF THE PNEUMATIC SYSTEM WEIGHT. THE BOTTLE WEIGHT WAS DETERMINED BY RATIOING THE SIVB BOTTLE WEIGHT BY THE RATIO OF THE SPACE SHUTTLE STORAGE PRESSURE TO THE SIVB STORAGE PRESSURE, 4500 PSI TO 3000 PSI; THE BURST SAFETY FACTORS 2.0 AND 2.5; AND THE 1.07 PREMIUM STOCK FACTOR. BOTTLE SUPPORTS ARE FROM THE SIVB

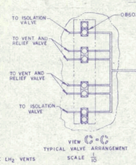
WITH THE EXCEPTION OF THE LINES, THE REMAINING HARDWARE WAS BASED ON EXISTING HARDWARE, EITHER DIRECTLY OR ADJUSTED FOR CRITICAL PARAMETERS.

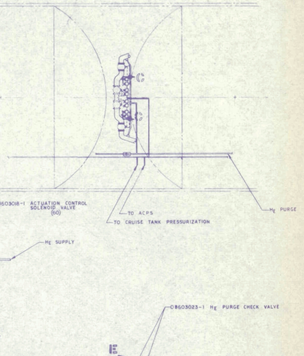
THE LINE WEIGHTS WERE DETERMINED BY DETAILED WEIGHT ANALYSIS BASED ON THE PROPOSED PNEUMATIC PLUMBING SYSTEM. ARMCO 21-6-9 STAINLESS STEEL WAS UTILIZED AT STANDARD GAUGES.

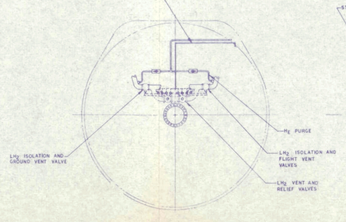


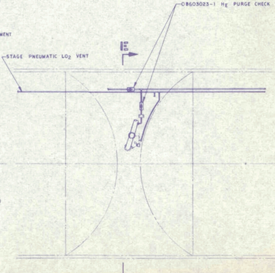


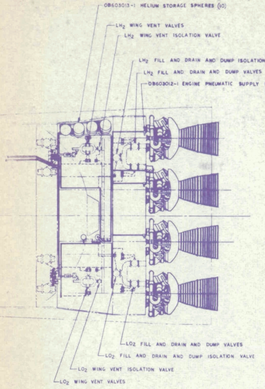


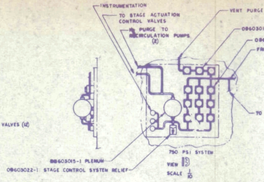


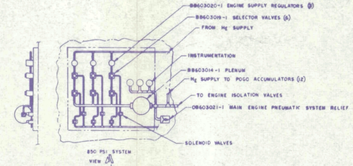


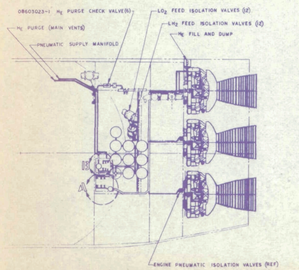


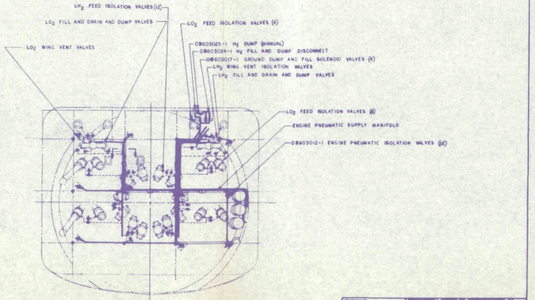












CONTRACT NO. NAS9-12200 DSR NO. 30-1

DRAWN			
CHECKED			
APPROVED			
MDC			

BOOSTER MAIN PROPULSION PNEUMATIC SYSTEM MCD 256-2CB

SIZE	CAGE IDENT NO.	DRAWING NO.	REV
E	16995	256-20-0025	A

SCALE NONE WEIGHT N/A

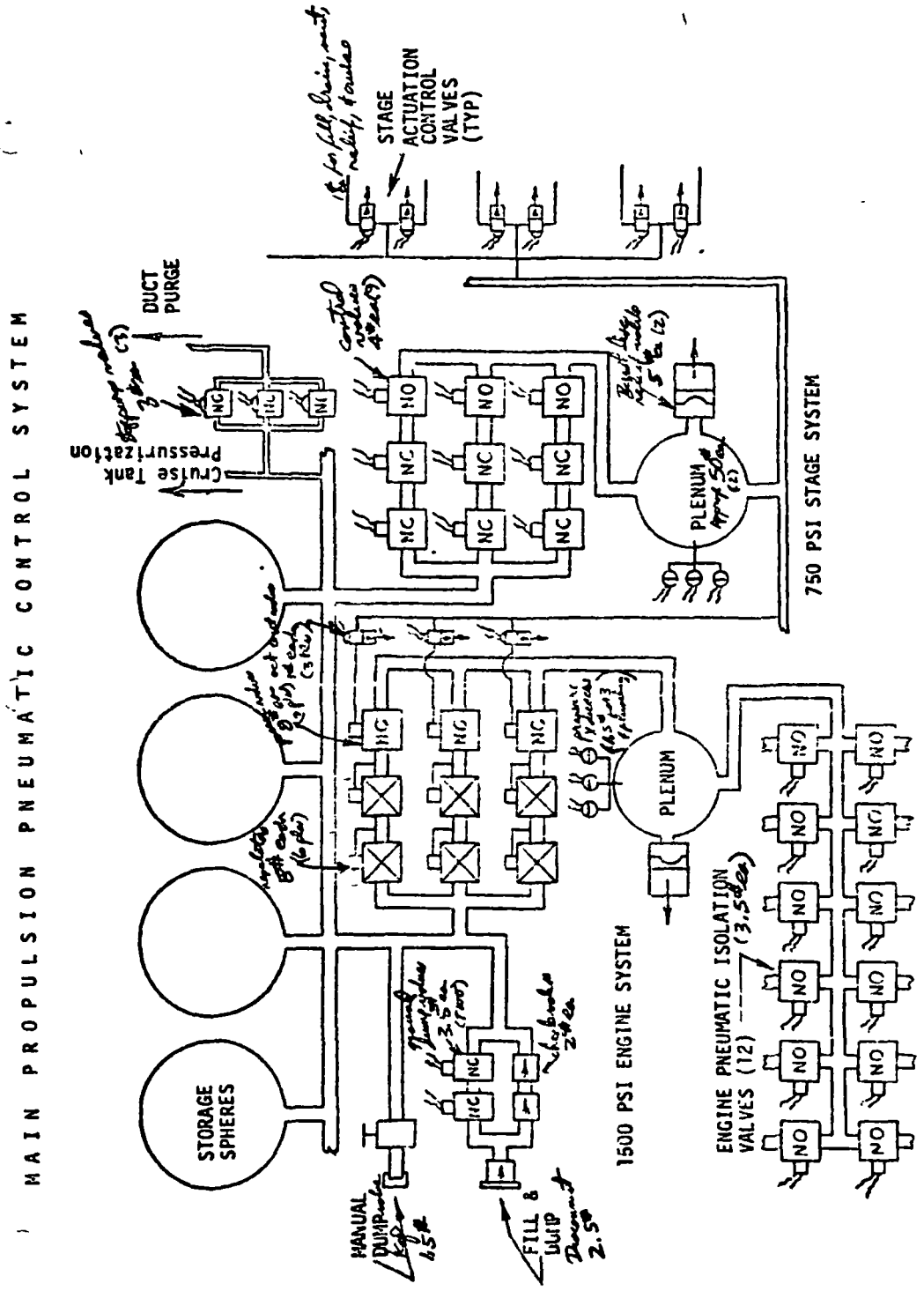
(PRIMARILY FOR ASCENT PROPULSION)

PNEUMATIC SYSTEM (DRY)

	WEIGHT
He BOTTLES (8 @ 120#) DRY	960
TEMPERATURE CONTROL JACKETS & DUCTS	108.
He BOTTLE SUPPORTS (8 @ 10# ea)	80.
MANUAL DUMP VALVE & CAP (1 @ 1.5#)	1.5
GROUND DUMP VALVES (2 @ 3.5# ea.)	7
FILL & DUMP DISCONNECT (1 @ 2.5#)	2.5
FILL & DUMP CHECK VALVES (2 @ 2#)	4.
REGULATORS (6 @ 8#)	48.
PRESSURE VALVES (3 @ 8#)	24.
ACTUATION CONTROL VALVES (3 @ 1#)	3.
PRESSURE XDUCERS (2 @ 1.5# ea.)	3.
PLENUMS (2 @ 50#)	100.
ENGINE PNEUMATIC ISOLATION VALVES (2 @ 3.5#)	42.
BURST DISC & RELIEF VALVES (2 @ 5#)	10.
CONTROL VALVES (9 @ 4#)	36.
STAGE PURGE VALVES (3 @ 3#)	9.
CHECK VALVES (8 X .5# / NOT SHOWN ON SCHEMATIC)	4.
PNEUMATIC LINE	491
SUPPORTS, CONTROLS & MISC (25% OF VALVES, LINES, PLENUMS) (785#)	196
TOTAL	2129

IT IS POSSIBLE THAT INCREASED HELIUM REQUIREMENTS MAY RESULT IN ADDITIONAL BOTTLES. SEE SSPI-E450-577, SECTION 4.1.10 FOR FINAL REQUIREMENTS.

25-3-6 (23 SEP 70)


MAIN PROPULSION PNEUMATIC CONTROL SYSTEM
STAGE ACTUATION CONTROL VALVES (TYP)
DUCT PURGE
Cruise Tank Pressurization
STORAGE SPHERES
PLENUM
750 PSI STAGE SYSTEM
1500 PSI ENGINE SYSTEM
ENGINE PNEUMATIC ISOLATION VALVES (12)
NO
NC

PNEUMATIC SYSTEM

BOTTLES & SUPPORTS

BOTTLES [8 @ 110 × $\frac{4500}{3000}$ × $\frac{2.0}{2.5}$ × $\frac{1}{1.07}$ = 120)]	960#
SUPPORTS (SIIB) [8 @ 10#]	80#
(dry) BOTTLES & SUPTS	1040#

TEMPERATURE CONTROL JACKETING

3# per bottle for SIIB-NYLON → 6#/BOTTLE REF (ALUMINUM FOR REUSE (OR SILICON CLOTH)

Ducting est 60# (9# return)

JACKETS (8 @ 6#)	48
DUCTS	60
TOTAL TEMPERATURE CONTROL JACKETS & DUCTS	108#

25-6-0 (23 SEP 70)

D

PNEUMATIC LINE SUMMARY

3" LINES	209
2" LINES	175
3/4" LINES	32
1/2" LINES	37
1/4" LINES	38
TOTAL	491

PNEUMATIC LINES

2" LINE - HE SUPPLY TO 1500 PSI REGULATION

L = 100 + 105 + 374 + 105 + 90 = 774"

WT = 774"(.226 LB/IN) = 175

3" ENGINE SUPPLY MANIFOLD

L = 98 + 227 + 230 + 115 = 670"

WT = 670"(.312 LB/IN) = 209

3/4" MANIFOLD TO ENGINE ISOLATION VALVES

ENGINE	#1	L = 80 + 75 =	155"
	#2	L =	75"
	#3	L =	75"
	#4	L = 104 + 75 =	179"
	#5	L = 80 + 75 =	155"
	#6	L =	75"
	#7	L =	75"
	#8	L =	75"
	#9	L = 80 + 75 =	155"
	#10	L =	75"
	#11	L =	75"
	#12	L = 95 + 75	170"
			1339"

WT = 1339"(.0225 LB/IN) = 30

3/4" 4500 PSI SUPPLY TO 750 PSI REGULATION

L = 60"

WT = 60"(.0362 LB/IN) = 2

1/2" MANIFOLD FOR REF VALVES

L = 98 + 235 + 125 + 225 + 65 + 100 = 848"

WT = 848"(.00889 LB/IN) = 8

1/2" SUPPLY LINE TO FORWARD VENT & ISOLATION VALVES

L = 55 + 220 + 120 + 1915 + 1095 = 3255"

WT = 3255"(.00884 LB/IN) 29

PNEUMATIC LINES (CONT.)

1/4" LINES FROM 1/2" SUPPLY

To LOX Feed Isolation Valves	
L = 12 (100 + 70 + 110) =	3,360"
To LH_2 Feed Isolation Valves	
L = 12 (30 + 20 + 15 + 20 + 10)	1,140"
To LH_2 Fill, Drain, Dump & Isolation Valves	
L = 65 + 60 + 30 + 80 + 30 =	265"
To LOX Fill, Drain, Dump & Isolation Valves	
L = 10 + 75 + 40 + 80 =	215"
To LH_2 Ring Vent & Isolation Valves	
L = 35 + 25 + 60 + 20 =	140"
To LOX Ring Vent & Isolation Valves	
L = 10 + 30 + 30 + 30 =	100"
Vent System Purge Line	
L = 60 + 215 + 90 + 170 + 2720	3465"
To LH_2 Vent & Isolation Valves	
L = 20 + 30 + 60 + 90 =	200"
To LOX Vent & Isolation Valves	
L = 65 + 90 + 100 =	205
Total Length Of 1/4" Lines	9,090"
WT = 9090" (.00416 LB/IN)	38 LB

PNEUMATIC LINES 3-1-71 G

2" LINE - 4500 ±100 PSI SUPPLY TO 1500 PSI REGULATOR

$t = \frac{ESPR}{\sigma} = \frac{2.5(4,600)(1)}{95,000} = .121$ MIN = .131 NOM ±0.010

USE $t = .134$ @ 22309 (.286/.283) = .226 LB/IN

3" LINE - 1500 ±100 PSI ENGINE MANIFOLD.

$t = \frac{ESPR}{\sigma} = \frac{4(1,600)(1.5)}{95,000} = .101$ MIN = .111 NOM ±0.010

USE $t = .120$ @ .30835 (.286/.283) = .312 LB/IN

3/4" LINE - 1500 ±100 PSI ENGINE TAP OFF LINES

$t = \frac{ESPR}{\sigma} = \frac{4(1,600)(.375)}{95,000} = .0252$ MIN - .0302 NOM ±0.005

USE $t = .035$ @ .02233 (.286/.283) = .0225 LB/IN

3/4" LINE - 4500 ±100 PSI SUPPLY LINE TO 750 PSI REGEGULATOR

$t = \frac{ESPR}{\sigma} = \frac{2.5(4,600)(.375)}{95,000} = .0454$ MIN = .0504 NOM ±0.005

USE $t = .058$ @ .03581 (.286/.283) = .03624 LB/IN

1/2" LINE - 700 - 800 PSI

$t = \frac{ESPR}{\sigma} = \frac{4(800)(.25)}{95,000} = .0084$ $t_{MIN} = .020$

USE $t = .020$ @ .00874 (.286/.283) = .0029 LB/IN

1/2" LINE - 700 - 800 PSI

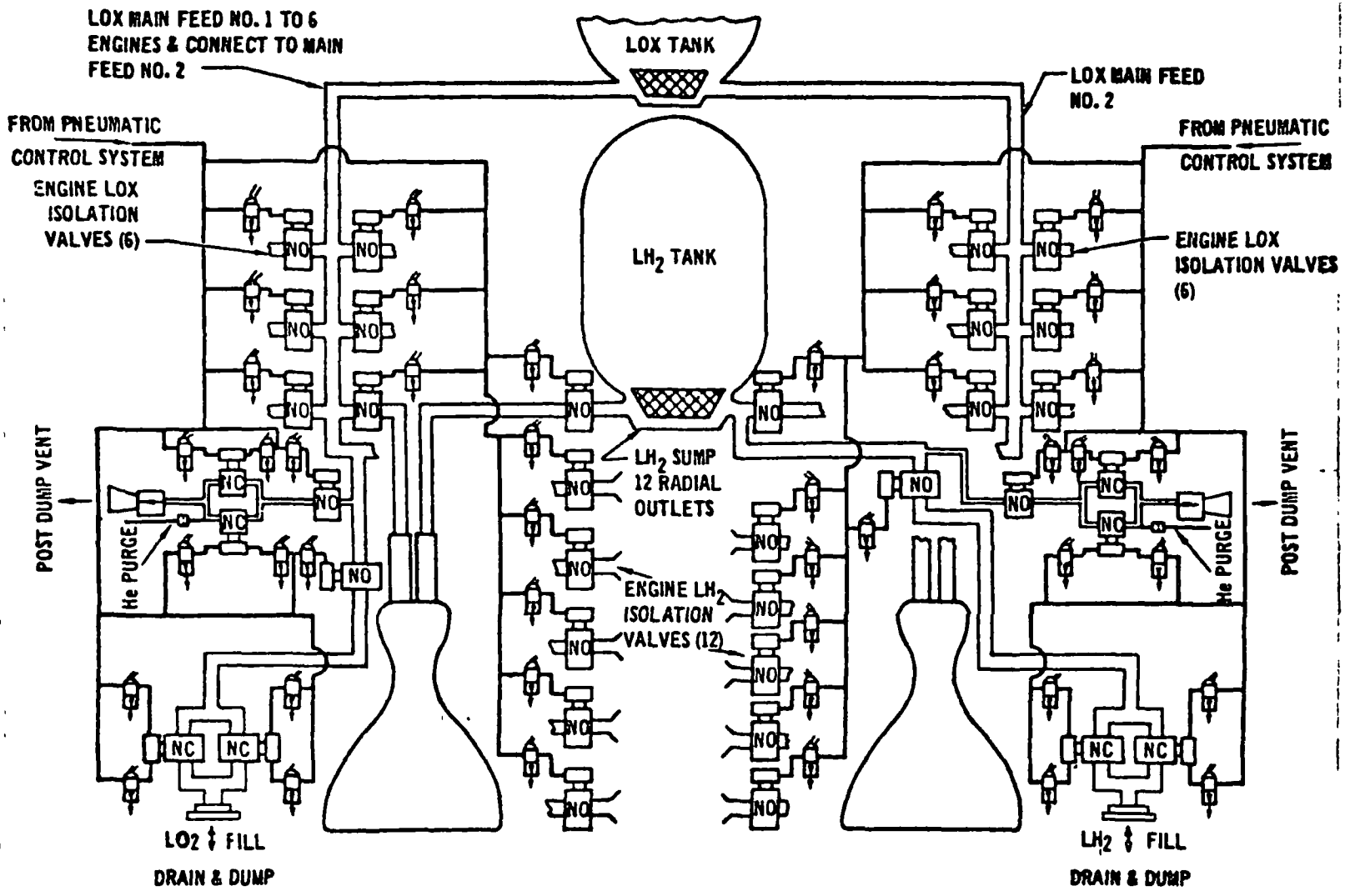
$t = \frac{ESPR}{\sigma} = \frac{4(800)(.125)}{95,000} = .0042$ $t_{MIN} = .02$

USE $t = .020$ @ .00412 (.286/.283) = .00416 LB/IN

PROPELLANT SYSTEMS

VALVES, BELLOWS, DISCONNECTS, AND FLANGES ARE BASED ON EXISTING HARDWARE, VENDOR DATA OR SCALING OF SAME. DUCT WEIGHTS ARE BASED ON DETAILED ANALYSIS OF LAYOUTS. WEIGHT ESTIMATION CURVES FOR VALVES AND BELLOWS ARE SHOWN ON THE FOLLOWING PAGES.

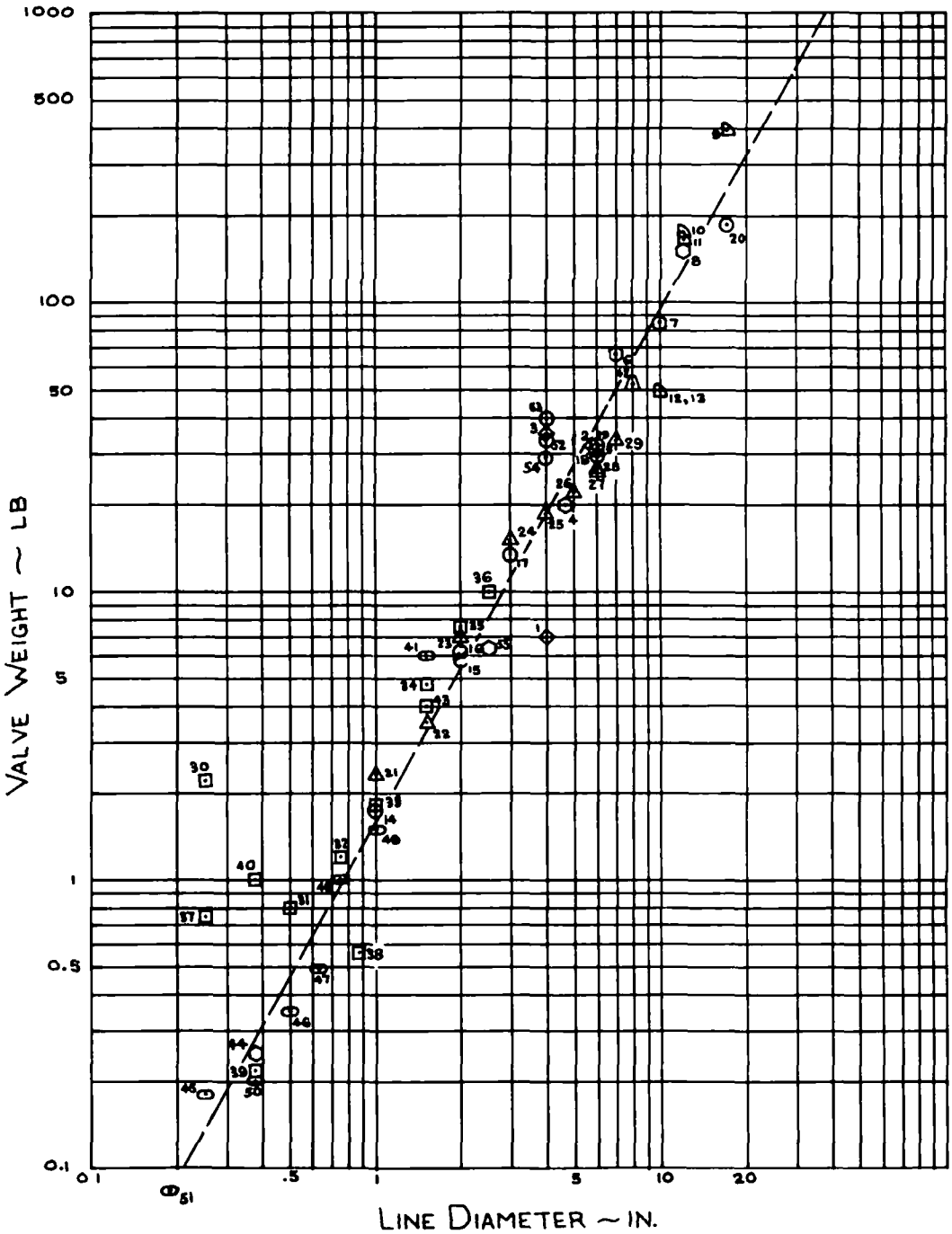
MAIN PROPULSION PROPELLANT SYSTEMS



CRYOGENIC VALVE WEIGHTS

TYPE OF VALVE

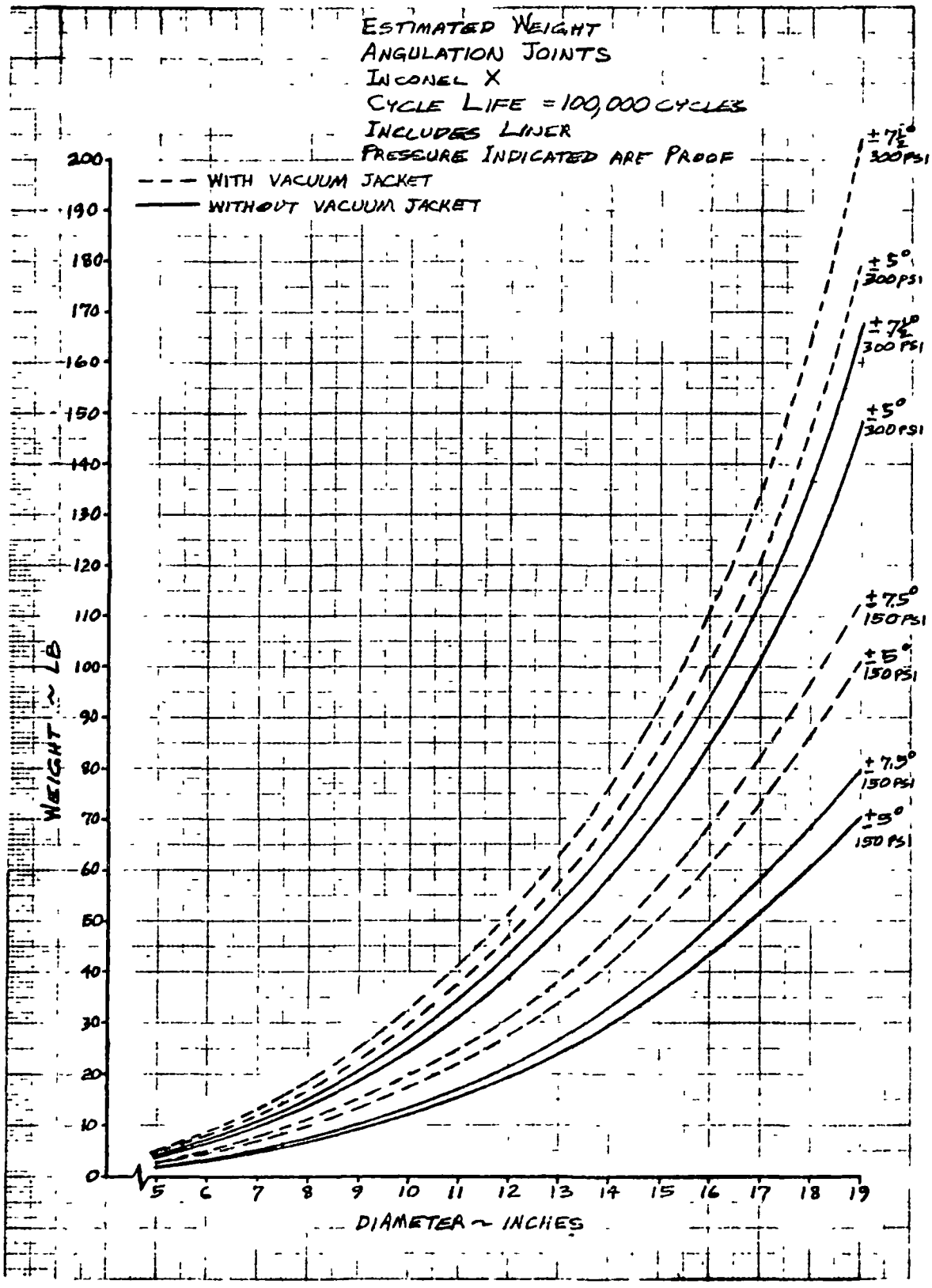
- ○ BALL VALVE
- □ SOLENOID
- △ BLADE
- ⬭ CHECK
- △ BUTTERFLY
- ⬡ RELIEF
- ◇ FILL AND DRAIN
- ⏢ PREVALVE

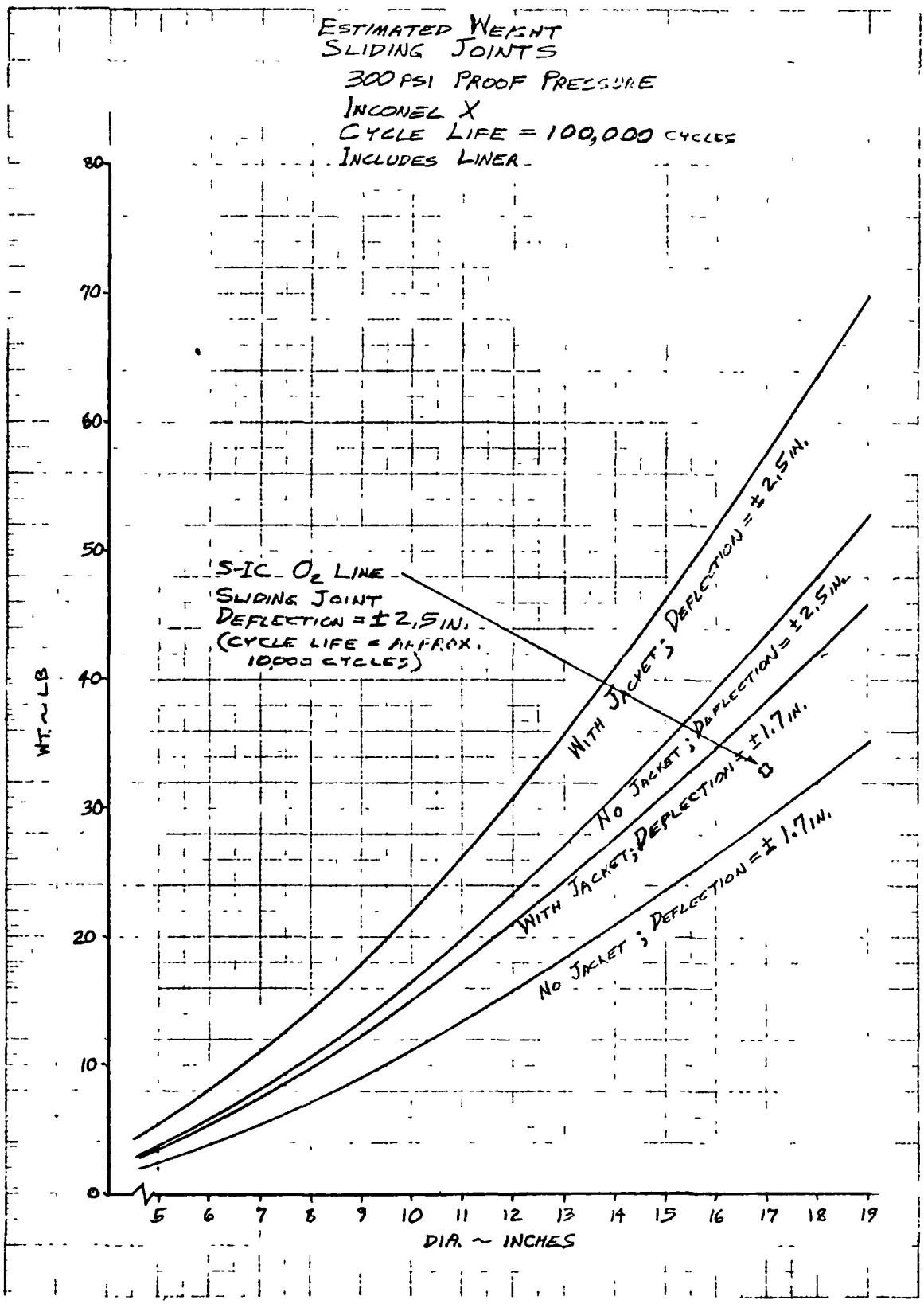


Cryogenic Valve Summary

No.	Type of Valve	Line Dia (in)	Valve Wt (lb)	Mfr.	Use
1	Fill and Drain	4	7	Fairchild	S-IV B
2	"	5.75	32	Parker	S-IC
3	"	4	35	Convair	Centaur
4	Vent and Relief	4.625	20	Ametek/Calmec	S-IV B
5	"	6	31	"	"
6	"	7	66.5	"	S-II
7	"	10	85	Whittaker	S-IC
8	"	12	150	"	"
9	Prevalve	17	395	"	"
10	"	12	175	"	
11	"	12	165	"	
12	"	10	50	Snaptite/Aervalve	S-IV
13	"	10	50	"	
14	Ball	1.00	1.73	Parker	
15	"	3.00	5.80	"	
16	"	2.00	6.20	"	
17	"	3.00	13.4	"	
18	"	6.00	30.0	"	
19	"	6.00	32.0	"	
20	"	17.00	185.		S-IC
21	Blade	1.00	2.30	Futurecraft	
22	"	1.50	3.50	"	
23	"	2.00	7.00	"	
24	"	3.00	10.5	"	
25	"	4.00	18 6	"	
26	"	5.00	22.0	"	
27	"	6.00	26.0	"	
28	"	6.00	26.8	"	
29	"	7.00	33.2	"	
30	Solenoid	.250	2.20	Valcor	
31	"	.500	.800	"	
32	"	.750	1.20	"	
33	"	1.00	1.80	"	
34	"	1.50	4.75	"	
35	"	2.00	7.55	"	
36	"	2.50	10.0	"	

No.	Type of Valve	Line Dia (in)	Valve Wt. (lb)	Mfr.
37	Solenoid	.250	.750	Wright
38	"	.875	.560	"
39	"	.375	.218	"
40	"	.375	1.00	NAR
41	Check	1.50	6.00	"
42	Buttertly	8.00	52.0	"
43	Solenoid	1.50	4.0	"
44	Relief	.375	.250	"
45	Check	.250	.180 ~~.150~~	Circle Seal
46	"	.500	.350 ~~.300~~	"
47	"	.625	.490 ~~.420~~	"
48	"	.750	1.000	"
49	"	1.000	1.500	"
50	"	.375	.200	"
51	"	.1825	.08	"
52	Ball	4	34	
53	"	4	40	
54	"	4	29	
55	Vent and Relief	2.5	6.4	


ESTIMATED WEIGHT
ANGULATION JOINTS
INCONEL X
CYCLE LIFE = 100,000 CYCLES
INCLUDES LINER
PRESSURE INDICATED ARE PROOF
--- WITH VACUUM JACKET
——— WITHOUT VACUUM JACKET
±7½° 300 PSI
±5° 300 PSI
±7½° 300 PSI
±5° 300 PSI
±7.5° 150 PSI
±5° 150 PSI
±7.5° 150 PSI
±5° 150 PSI
WEIGHT ~ LB
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
DIAMETER ~ INCHES


ESTIMATED WEIGHT
SLIDING JOINTS
300 PSI PROOF PRESSURE
INCONEL X
CYCLE LIFE = 100,000 CYCLES
INCLUDES LINER
S-IC O_2 LINE
SLIDING JOINT
DEFLECTION = ±2.5 IN.
(CYCLE LIFE = APPROX. 10,000 CYCLES)
WITH JACKET; DEFLECTION = ±2.5 IN.
NO JACKET; DEFLECTION = ±2.5 IN.
WITH JACKET; DEFLECTION = ±1.7 IN.
NO JACKET; DEFLECTION = ±1.7 IN.
WT. ~ LB
0
10
20
30
40
50
60
70
80
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
DIA. ~ INCHES

FACTOR FOR SUPPORTS & MISCELLANEOUS PARTS

A FACTOR OF 31.70% WAS OBTAINED FOR SII WHICH HAS A TOTAL FEED SYSTEM WEIGHT OF APPROXIMATELY 500LB, AND A FACTOR OF 20.18% WAS OBTAINED FOR SIC WHICH HAS A TOTAL FEED SYSTEM WEIGHT OF ABOUT 23,000LB. THE SIC FACTOR SHOULD BE MORE ACCURATE THAN THE SII DUE TO SIZE EFFECTS. HOWEVER, MINOR WEIGHT PENALTIES SUCH AS WELDS, INCREASED DUCT THICKNESS IN ELBOWS, ETC. WERE NOT INCLUDED IN THE SPACE SHUTTLE ANALYSIS. ALL FACTORS CONSIDERED IT SEEMS REASONABLE TO ADD 4.82% TO THE SIC RATIO, AND USE AN ALLOWANCE OF 25% FOR THE SPACE SHUTTLE FEED SYSTEM SUPPORTS AND MISCELLANEOUS WEIGHT ITEMS.

FACTOR FOR SUPPORTS & MISC.

SIII-8 APR '65 T=20K VAC. (SIX ENGINES)

(D&D) FEED & DISTRIBUTION SYSTEM	315.596
– FUEL DUCTS (6)	-222.600
SUPPORTS & MISC	92.996

(DHD) FEED & DIST. SYSTEM	158.281	
– SUPPLY DUCTS (6)	-120.720	137.220 DUCTS & VALVES
– LINE (1)	- 3.080	
– DUCT (1)	- 6.920	
– VALVE (1)	-6.500	
SUPPORTS & MISC	21.061	

$$FACTOR = \frac{92.996 + 21.061}{222.600 + 137.220} = 31.70\%$$

SIC 25 MAR '70

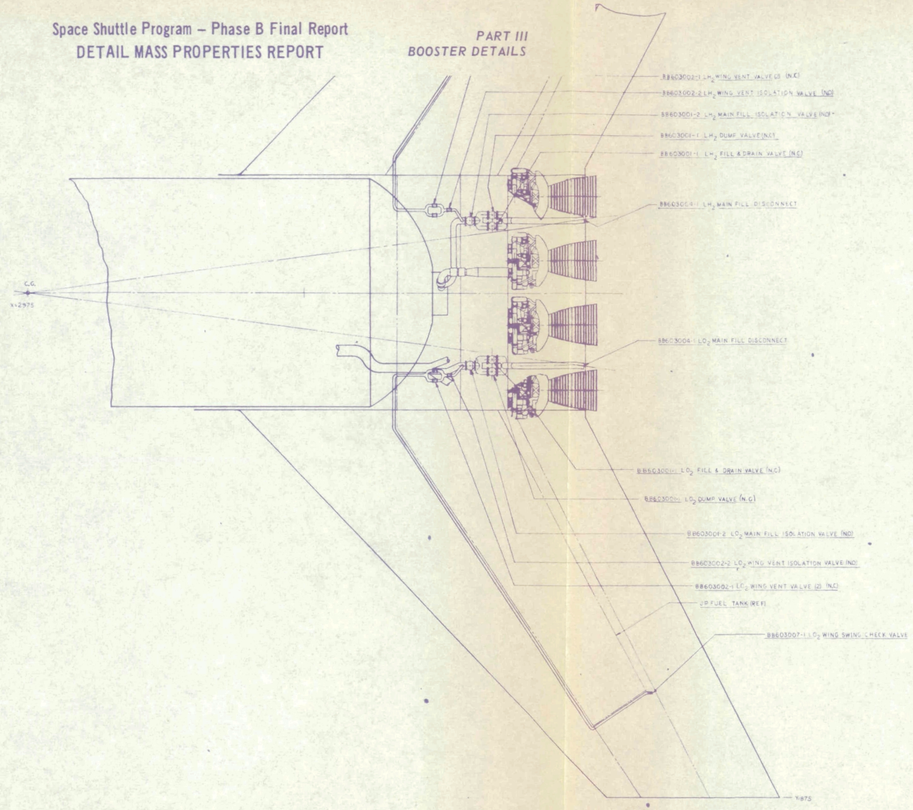
	FUEL	LOX
PVC DUCTS	3585.4	4282.0
SUCTION DUCTS	1384.0	6192.0
PRE VALVES	1080.0	1965.0
SPOOLS	—	591.8*
SUBTOTAL VALVES & LINES	6049.4	13030.8
TOTAL VALVES & LINES	(19080.2)	
SUPPORTS	120.5	3729.7*
TOTAL	(3850.2)	

$$FACTOR = \frac{3850.2}{19080.2} = 20.18\%$$

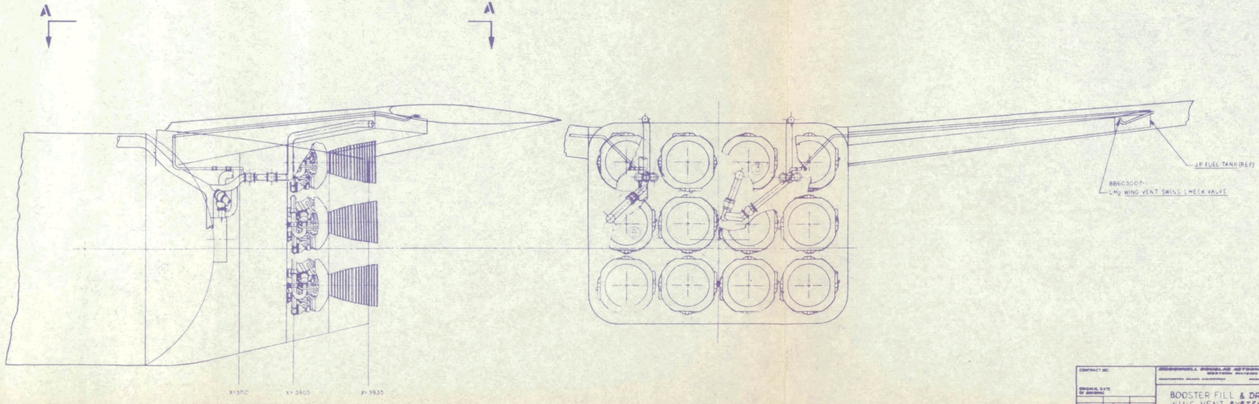
* WERE CHARGED TO SUPPORTS (INCORRECTLY) AND REDUCES WEIGHT OF SUPPORTS BY 591.8 LB.

FILL, DRAIN & DUMP (ASCENT PROPULSION)

	WT
LOX FILL, DRAIN & DUMP	
FILL & DRAIN VALVE (10" DIA)	100
ISOLATION VALVE (10" DIA)	100
DUMP VALVE (10" DIA)	100
GIMBAL BELLOWS (2 @ 28 LB-EA)	56
DISCONNECT (FLIGHT HALF)	15
DUCT TO VALVE FLANGE (6 @ 10.4 LB-EA)	62
DUCTING	77
RE-ENTRY VENT-DUMP	42
SUPPORTS & MISC (25% OF 552)	138
SUBTOTAL	690
LH_2 FILL, DRAIN & DUMP	
FILL & DRAIN VALVE (10" DIA)	100
ISOLATION VALVE (10" DIA)	100
DUMP VALVE (10" DIA)	100
GIMBAL BELLOWS (2 @ 28 LB-EA)	56
DISCONNECT (FLIGHT HALF)	15
DUCT TO VALVE FLANGE (6 @ 10.9 LB-EA)	62
DUCTING	166
RE-ENTRY VENT DUMP	42
SUPPORTS & MISC (25% OF 641)	160
SUBTOTAL	801
TOTAL LOX & LH_2 FILL, DRAIN & DUMP	1,591



VIEW A-A



CONTRACT NO.	MCDONNELL DOUGLAS ASTRONAUTICS CO. EASTERN DIVISION
ORIGINAL DATE OF DRAWING	
PROJ. MGR.	1-26-72
CHECKED	
DESIGNED	
PROJECT ENGINEER	
CONTRACT OFFICIAL	

BOOSTER FILL & DRAIN DUMP
WING VENT SYSTEM
MODEL 256-20B

SIZE	CODE IDENT NO.	DRAWING NO.	REV
	18355	256-20-0022	1

SCALE 1/20 SHEET 1 OF

(9)

LOX FILL, DRAIN & DUMP LINE

THE ULTIMATE DESIGN PRESSURE IS 1.5 TIMES THE MAXIMUM TRANSIENT (SURGE) PRESSURE OF 375 PSI WHICH IS EQUAL TO 562.5 PSI

DUCT MATERIAL: ARMCO 21-6-9 STAINLESS STEEL
σ = 95,000 PSI
ρ = 0.286 PSI
DIAMETER = 10"

$t = \frac{PR}{\sigma} = \frac{562.5(5)}{95{,}000} = 0.0296$ MIN = $0.033^{1.003}_{\text{NOM}}$

USE STANDARD .035

UNIT WT = $\pi(10)(1)(.035)(.286) = .315$ LB/IN

DUCT LENGTH = 245"

FILL, DRAIN & DUMP LINE WT = $245(.315) =$ **77 LB**

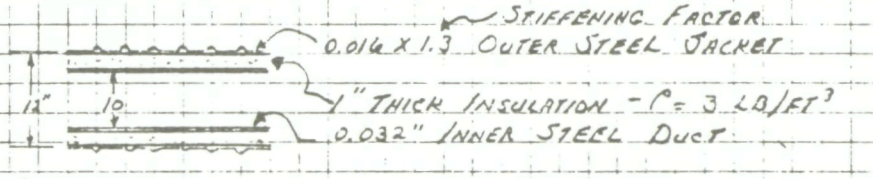
LH2 FILL, DRAIN & DUMP LINE

THE ULTIMATE DESIGN PRESSURE IS 1.5 TIMES THE MAXIMUM TRANSIENT (SURGE) PRESSURE OF 100 PSI WHICH IS EQUAL TO 150 PSI

$t = \frac{PR}{\sigma} = \frac{150(5)}{95{,}000} = .0079$ USE 0.032 MIN PER OVERTAN

WT UNINSULATED DUCT = $\pi(10)(1)(.032)(.286) = 0.287$ LB/IN

INSULATED DUCT:



UNIT WT:

INNER DUCT	=	0.287
INSULATION = $\pi(11)(1)(12)(3/1728)$	=	0.060
OUTER JACKET = $\pi(12)(.016 \times 1.3)(.286)$	=	0.224
		0.571 LB/IN

INSULATED DUCT LENGTH = 270"
UNINSULATED LENGTH = 40"

TOTAL FILL, DRAIN, DUMP LINE WT = $270^{15\frac{1}{2}}(.571) + 40^{12}(.287) =$ **164 LB**

(10)

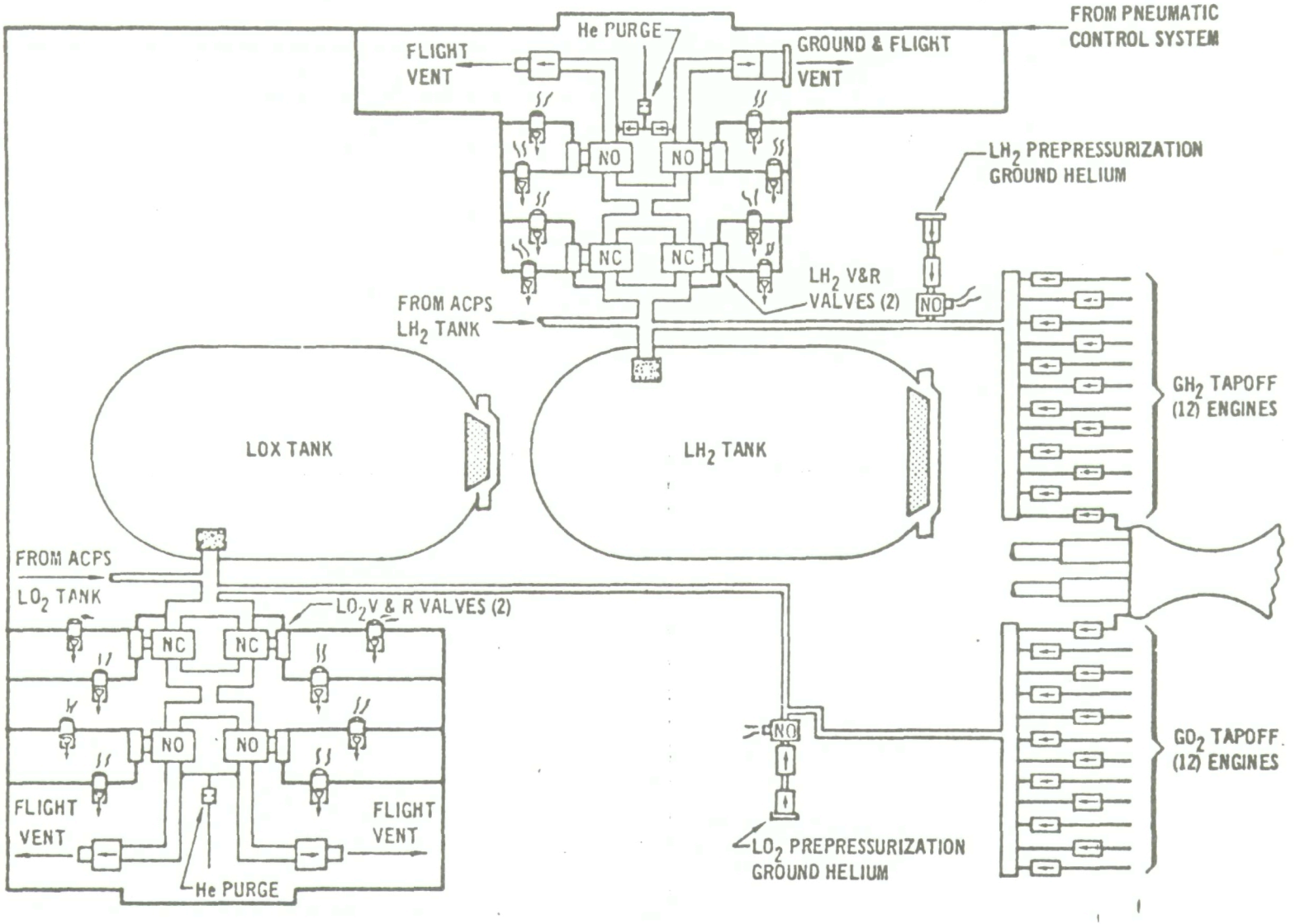
WING RE-ENTRY VENT

LOX & LH2 ASSYS ARE IDENTICAL

DUCT:
MATERIAL: ALUMINUM
DIA : 4"
t : 0.016"
LENGTH : 420"
WT = π(4)(1)(.016)(.1) = .0202 LB/IN

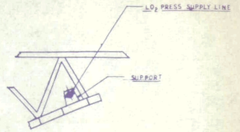
DUCT WT = 420(.0202)	=	8.5
ISOLATION VALVE (N.O.)	=	7.0
SHUT-OFF VALVES (N.C.) (2 @ 7LB-EA)	=	14.0
FLANGES (7 @ 1 LB EA)	=	7.0
CHECK VALVE	=	1.5
BELLOWS RESTRAINED (1 @ 4LB)	=	4.0
TOTAL ASSY		42.0 LB

MAIN PROPULSION PRESSURIZATION AND VENT SYSTEMS

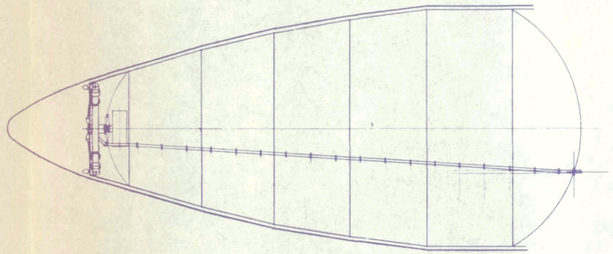


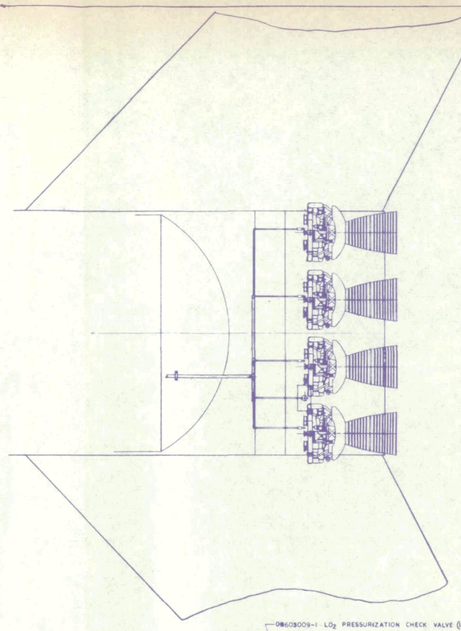
LOX PRESSURIZATION - VENT SYSTEM

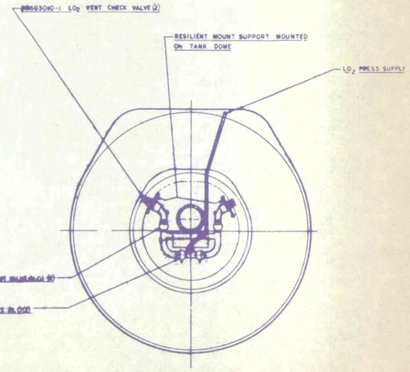
	WT
PRESSURIZATION: MAIN PRESSURIZATION LINE	577
PRESSURIZATION: MANIFOLD ASSY	61
PRESSURIZATION: GROUND PRESSURIZATION ASSY	4
PRESSURIZATION: GROUND CHECKOUT ASSY	3
ISOLATION VALVES (2 @ 100 LB-EA)	200
VENT & RELIEF VALVES (2 @ 100 LB-EA)	200
CHECK VALVES (10" DIA - 2 @ 20 LB-EA)	40
VENT DUCT ASSY	181
FLANGES (10" DIA - 8 @ 10.4 LB-EA)	83
DIFFUSER ASSY	37
SUPPORT & MISC (25 % OF 1386)	346
TOTAL LOX SYSTEM	1732
TOTAL PRESSURIZATION & VENT SYSTEM	3276

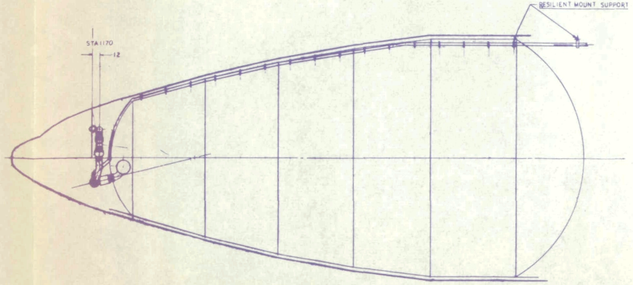


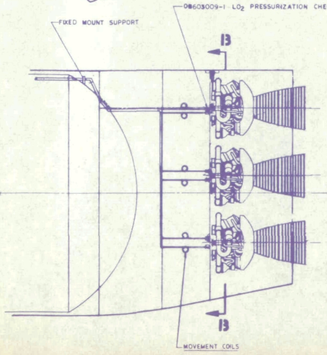
VIEW A
LO_2 PRESSURE SUPPLY LINE WITH RESILIENT MOUNT SUPPORT

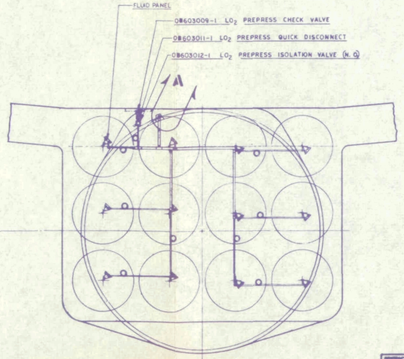












VIEW B-B

BOOSTER-LO2 VENT & PRESSURIZATION SYSTEM MOD 256-208

CONTRACT NO.	DRAWING NO.	REV
	18355	256-20-0023	A

(3)

LOX PRESSURIZATION SYSTEM

LOX MAIN PRESSURIZATION LINE (STA 1236 -3600)

DUCT (4" DIA - 2,830" - .058" WALL)	=	553 LB
BELLOWS (6 @ 4 LB-EA.)		24 LB
TOTAL DUCT ASSY		577 LB

MANIFOLD ASSY

DUCT (3" DIA - 225" - .042 WALL)	=	25.2 LB
DUCT (2" DIA - 200" - .035 WALL)	=	1.3 LB
DUCT (0.75" DIA - 1,120" - .016 WALL)	=	12.0 LB
CHECK VALVES (12 @ 0.75 LB-EA)	=	9.0 LB
BELLOWS (3" DIA - 2 @ 3.5 LB-EA)	=	7.0 LB
BELLOWS (2" DIA - 2 @ 3.0 LB-EA)	=	6.0 LB
TOTAL MANIFOLD WT	=	60.5
		61 LB

GROUND PRESSURIZATION ASSY

DUCT (0.75" DIA - 150" - .016 WALL)	=	1.6 LB
DISCONNECT/CHECK VALVE		1.5 LB
CHECK VALVE		0.8 LB
TOTAL ASSY		3.9 LB
		4 LB

GROUND CHECKOUT ASSY

PRESSURE TRANSDUCERS (3 @ .5 LB-EA)	1.5 LB
1/4" TUBING (225" @ .0034 LB/IN)	.8 LB
TOTAL ASSY	2.3 LB
	3 LB

③

LOX PRESSURIZATION SYSTEM

DUCTING

0.75" DIA X 0.016 WALL	=	0.0107	LB/IN
2.00" DIA X 0.035 WALL	=	0.0620	LB/IN
3.00" DIA X 0.042 WALL	=	0.1120	LB/IN
4.00" DIA X 0.058 WALL	=	0.2060	LB/IN

$\rho = 0.286$ LB/IN³

0.75" DIA ENGINE TAP OFF LINES

LENGTH = 12(90) + 6(115) + 2(125) = 1,120"

WT = 1,120(.0107) = **12 LB**

2.00" DIA MANIFOLD

LENGTH = 2(100) = 200

WT = 200(.0620) = **1.3 LB**

3.00" DIA MANIFOLD

LENGTH = 225"

WT = 225(.1120) = **25.2 LB**

4.00" PRESSURIZATION LINE

LENGTH = 90 + 80 + 20 + 2,340 + 150 = 2,680"

WT = 2,680(.206) = **553 LB**

CHECK VALVES - 0.75" DIA - 12 REQ

WT = 12(0.75) = **9 LB**

BELLOWS:

4" DIA - 6 REQ	WT = 6(4) =	**24 LB**
3" DIA - 2 REQ	WT = 2(3.5) =	**7 LB**
2" DIA - 2 REQ	WT = 2(3.0) =	**6 LB**

0.075" DIA GROUND PRESSURIZATION LINE

LENGTH = 150"

WT = 150(.0107) = **1.6 LB**

34

PRESSURIZATION LINE WALL THICKNESS

1" DIA

$$t = \frac{F.S.PR}{\sigma} = \frac{2.5\,(1,000)\,2}{95,000} = .0526_{MIN} = .056^{\pm 0.003}_{NOM}$$

STANDARD GAGE = .058

3" DIA

$$t = \frac{F.S.PR}{\sigma} = \frac{2.5\,(1,000)\,1.5}{95,000} = .0395_{MIN} = .043^{\pm 0.003}_{NOM}$$

STANDARD GAGE = .042

2" DIA

$$t = \frac{F.S.PR}{\sigma} = \frac{2.5\,(1,000)\,1}{95,000} = .0264_{MIN} = .030^{\pm 0.003}$$

STANDARD GAGE = .035

0.75" DIA

$$t = \frac{F.S.PR}{\sigma} = \frac{2.5\,(1,000)\,.375}{95,000} = .0099$$ USE 0.016 MIN (PER OVERMAN)

STANDARD GAGE = .016

④

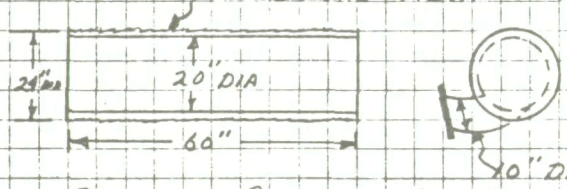
LOX VENT SYSTEM

VENT DUCT ASSY

MATERIAL: STEEL
10" DIA
t = 0.032"
LENGTH = 154 108 + 70 + 30 + 50 = 273"
UNIT WT = 0.287 LB/IN (-50"-20" FOR 2 BELLOWS)

DUCT WT = 273 (.287) =	79	LB
BELLOWS - PRESS COMPENSATED (1 @ 28 LB)	28	LB
BELLOWS - RESTRAINED (2 @ 22 LB-EA)	44	LB
DISCONECT & END TERMINATING FLANGE	30	LB (15 LB-EA)
TOTAL DUCT ASSY	181	LB

DIFFUSER



MATERIAL: AL

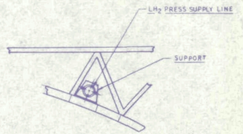
DIFFUSER CONSISTS OF A 20" DIA TUBE 60" LONG WITH 24" DIA END CAPS. THE 60" DIA TUBE IS SLOTTED AND COVERED WITH A WIRE MESH. THE BASIC DIFFUSER IS WELDED TO A 10" DIA FLANGED DUCT FOR MOUNTING TO THE END BLKHD. A 30% FACTOR IS ADDED TO TUBE WEIGHT FOR STIFFENING & MESH MOUNTING.

END CAPS - WT = 2 π (12)² (.032) (.1) =	2.9	LB	
TUBE - WT = π (20) (60) (.032) (.1) (1.3) =	15.7	LB	
WIRE MESH = π (24) (60) (.4/144) =	12.6	LB	
CONNECTING DUCT = π (10) (15) (.032) (.1) =	1.5	LB	
FLANGE =	4.0	LB	
TOTAL DIFFUSER ASSY	36.7		37 LB

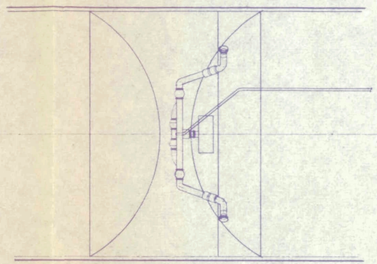
(5)

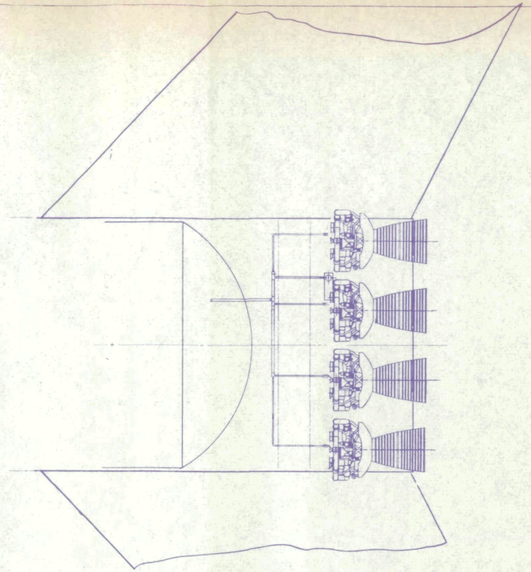
LH_2 PRESSURIZATION-VENT SYSTEM

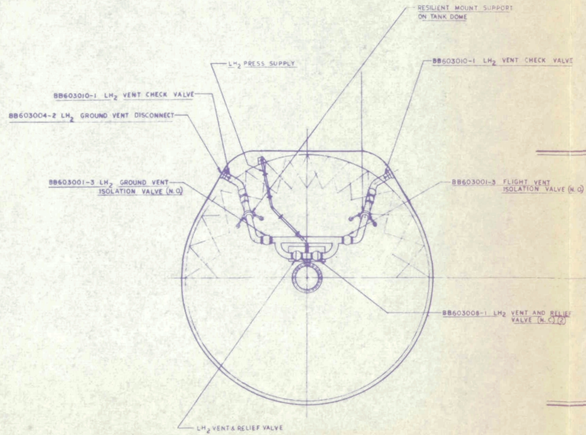
		WT
PRESSURIZATION	MAIN PRESSURIZATION LINE	397
	MANIFOLD ASSY	61
	GROUND PRESSURIZATION ASSY	4
	GROUND CHECKOUT ASSY	3
	ISOLATION VALVES (2 @ 100 LB-EA)	200
	VENT & RELIEF VALVES (2 @ 85 LB-EA)	200
	CHECK VALVES (2 @ 20 LB-EA)	40
	VENT DUCT ASSY	222
	FLANGES (10" DIA - 8 @ 10.4 LB-EA)	83
	DIFFUSER ASSY	37
	SUPPORT & MISC (26% OF 1247)	312
	TOTAL LH_2 SYSTEM	1559

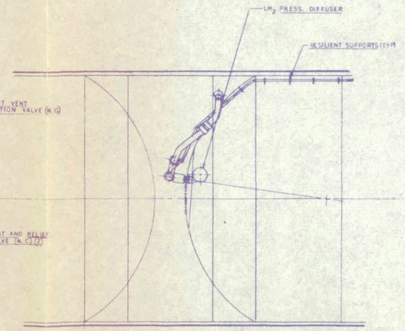


VIEW A
LH2 PRESS SUPPLY LINE WITH RESILIENT MOUNT SUPPORT

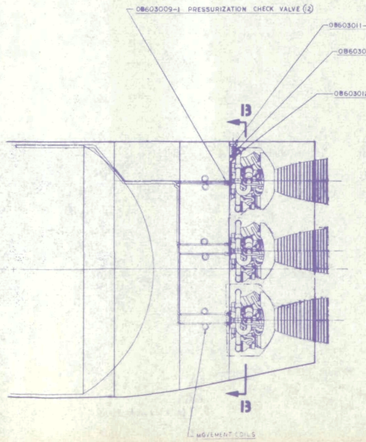


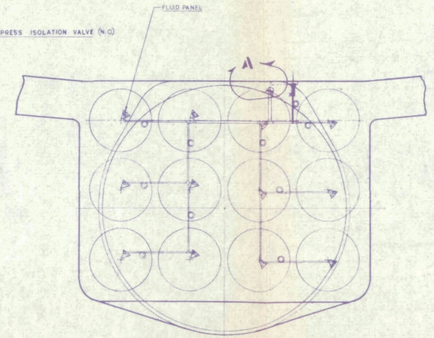






X-1883





VIEW B-B

CONTRACT NO.		MCDONNELL DOUGLAS ASTRONAUTICS CO.	
ORIGINAL DATE OF DRAWING		BOOSTER - LH2 VENT & PRESSURIZATION SYSTEM MOD 256 208	
PREPARED			
CHECKED			
ENGINEER			
DESIGN APPROVAL		CODE IDENT NO. 18355	DRAWING NO. 256-20-0024
CUSTOMER APPROVAL		SCALE NONE	SHEET 1 OF 1

(6)

LH_2 PRESSURIZATION SYSTEM

LH_2 MAIN PRESSURIZATION LINE

4" DIA. DUCT (STA 2163 - 3600)
t = 0.058"
LENGTH = 90 + 80 + 20 + 1390 + 230 = 1,810'
WT = 0.206 LB/IN

DUCT = 1,810 (.206) =	373 LB
BELLOWS (6 @ 4 LB-EA.)	24 LB
TOTAL DUCT ASSY	397 LB

MANIFOLD ASSY

WT = (SAME AS LOX SYSTEM) — 61 LB

GROUND PRESSURIZATION ASSY

WT = (SAME AS LOX SYSTEM) — 4 LB

GROUND CHECKOUT ASSY

WT = (SAME AS LOX SYSTEM) — 3 LB

⑦

LH_2 VENT SYSTEM

VENT DUCT ASSY

MATERIAL : STEEL
DIAMETER : 10"
t : 0.032"
UNIT WT : 0.287 LB/IN
LENGTH : 15 + 92 + 82 + 160 + 70 = 419"

DUCT WT = 419 (.287) =	120 LB
BELLOWS - PRESS COMPENSATED (1 @ 28 LB)	28 LB
BELLOWS - RESTRAINED (2 @ 22 LB-EA.)	44 LB
DISCONNECT (FLIGHT HALF)	15 LB
TERMINATING FLANGE	15 LB
TOTAL DUCT ASSY	222 LB

DIFFUSER

WT = (SAME AS LOX DIFFUSER) 37 LB

PROPELLANT LEVEL SENSING - ASCENT PROPULSION

MAIN LOX TANK

CAPACITANCE PROBE (15' @ 1 LB/FT)	15.0
TWELVE POINT LEVEL SENSORS @ .125 LB/SENSOR	1.5
ELECTRONICS PACKAGE	2.5
SUPPORT (25% FOR PROBE - 10% FOR REMAINING)	4.2
WIRING (INCLUDES SUPPORT)	11.2
	34.4

MAIN LH_2 TANK

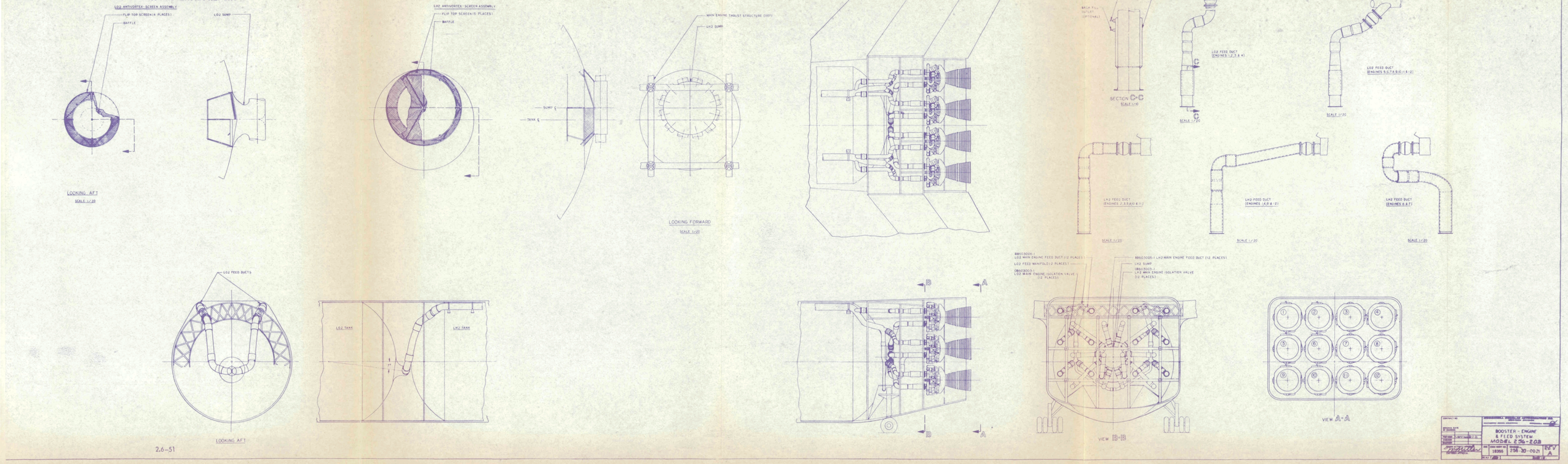
CAPACITANCE PROBE (20' @ 1 LB/FT)	20.0
NINE POINT LEVEL SENSORS @ .125 LB/SENSOR	1.1
ELECTRONICS PACKAGE	2.5
SUPPORT (25% FOR PROBE - 10% FOR REMAINING)	5.4
WIRING (INCLUDES SUPPORT)	11.2
	40.2

TOTAL 75

LO_2 FEED SYSTEM	WEIGHT
GIMBAL BELLOWS IN DUCTS (3X12=36, 12"D)	1548
DUCTS (12 BETWEEN MANIFOLDS & ENGINE, 12"D-15"D)	1510
POGO ACCUMULATORS (12)	754
MAINIFOLD BELLOWS (2-13"D, 2-8"D)	136
MANIFOLD (AFT OF STA 3553)	1101
ISOLATION VALVES (12, 12"D)	1740
DUCT TO VALVE FLANGES (24-12 PAIR - 12"D)	288
DUCT TO ENGINE FLANGES (12, 15"D)	180
MAIN DUCTS (2, 22"D FROM STA 2020 TO 3553)	2496
MAIN DUCT BELLOWS (10, 22"D)	1200
SUPPORTS & MISC. (25% OF ABOVE)	2738
SUBTOTAL	13691

LH_2 FEED SYSTEM	
GIMBAL BELLOWS IN DUCTS - JACKETED (3X12=36, 12"D)	1062
DUCTS (12 BETWEEN SUMP & ENGINES, 12"D-15"D)	860
DUCT INSULATION JACKETS	695
ISOLATION VALVES (12, 12"D)	1740
DUCT TO VALVE FLANGES (24-12 PAIR-12"D)	288
DUCT TO ENGINE FLANGES (12, 15"D)	180
SUPPORTS & MISC (25% OF ABOVE)	1206
SUBTOTAL	6031

TOTAL LO_2 & LH_2 FEED SYSTEM	19722*


LO2 ANTIVORTEX-SCREEN ASSEMBLY
FLIP TOP SCREEN (4 PLACES)
BAFFLE
LO2 SUMP
LOOKING AFT
SCALE 1/20
LH2 ANTIVORTEX-SCREEN ASSEMBLY
FLIP TOP SCREEN (6 PLACES)
BAFFLE
SUMP ℄
TANK ℄
MAIN ENGINE THRUST STRUCTURE (REF)
LH2 SUMP
LOOKING FORWARD
SCALE 1/20
POGO SUPPRESSION ACCUMULATOR (2 CUBIC FEET) (12 PLACES)
HELIUM SUPPLY
BACK FILL OUTLET (OPTIONAL)
SECTION C-C
SCALE 1/10
LO2 FEED DUCT (ENGINES 1,2,3 & 4)
SCALE 1/20
LO2 FEED DUCT (ENGINES 5,6,7,8,9,10,11 & 12)
SCALE 1/20
LH2 FEED DUCT (ENGINES 2,3,5,8,10 & 11)
SCALE 1/20
LH2 FEED DUCT (ENGINES 1,4,9 & 12)
SCALE 1/20
LH2 FEED DUCT (ENGINES 6 & 7)
SCALE 1/20
LO2 FEED DUCTS
LOOKING AFT
LO2 TANK
LH2 TANK
B
A
B
A
BB603006-1 LO2 MAIN ENGINE FEED DUCT (12 PLACES)
LO2 FEED MANIFOLD (2 PLACES)
OB603003-1 LO2 MAIN ENGINE ISOLATION VALVE (12 PLACES)
BB603005-1 LH2 MAIN ENGINE FEED DUCT (12 PLACES)
LH2 SUMP
OB603003-1 LH2 MAIN ENGINE ISOLATION VALVE (12 PLACES)
VIEW B-B
VIEW A-A
BOOSTER - ENGINE & FEED SYSTEM
MODEL 256-20B
18395
256-20-0021
REV A

DUCTS & MANIFOLDS

THE MAXIMUM TRANSIENT PRESSURE MULTIPLIED BY 1.667 AND 2.0 FACTORS OF SAFETY USING YIELD AND ULTIMATE STRESS VALUES, RESPECTIVELY WERE USED TO DESIGN FOR PRESSURE. MINIMUM GAUGE VALUES FOR STEEL WERE TAKE FROM ARP 735. ALUMINUM MINIMUM GAUGES WERE ESTIMATED BY MULTIPLIAG THE ARP 735* VALUES BY THE CUBE ROOT OF THE STEEL TO ALUMINUM YOUNG'S MODULUS RATIO.

* AEROSPACE RECOMMENDED PRACTICE 735, SOCIETY OF AUTOMOTIVE ENGINEERS, "AEROSPACE VEHICLE CRYOGENIC DUCT SYSTEMS."

LO_2 & LH_2 COMPONENTS

ITEM	QTY	WEIGHT EACH	WEIGHT
LO_2 DUCT BELLOWS (12"D) 300 PSI/1.5°	36	43	1548
LO_2 MANIFOLD BELLOWS (13"D) 300 PSI/1.5°	2	53	136
" " " (8"D) 300 PSI/1.5°	2	15	
LO_2 ISOLATION VALVES (12"D) SEGMENTED BALL	12	145	1740
LO_2 DUCT TO VALVE FLANGES (12"D) STEEL	24	12	288
LO_2 DUCT TO ENGINE FLANGES (15"D) STEEL	12	15	180
LO_2 MAIN DUCT BELLOWS (22"D) 150 PSI/1.5°	10	120	1200
LH_2 DUCT BELLOWS - JACKETED (12"D) 150 PSI/5°	18	28	1062
150 PSI/15°	18	31	
LH_2 ISOLATION VALVES (12"D) SEGMENTED BALL	12	145	1740
LH_2 DUCT TO VALVE FLANGES (12"D) STEEL	24	12	288
LH_2 DUCT TO ENGINE FLANGES (15"D) STEEL	12	15	180

LO_2 12 INDIVIDUAL DUCTS

TWELVE 12"D DUCTS – $L_{TOTAL} = 864"$
TWELVE DIFFUSERS – $L = 17"$ EACH
TWELVE, 15"D DUCTS – $L = 56"$ EACH

12"D DUCTS

L_{ij} : L = LENGTH; i, j = ENGINE NUMBERS // -36" FOR 3 BELLOWS, -20" ISO. VALVE

$L_{1,4} = 2(176 - 36 - 20) = 2(120) = \underline{240"}$
$L_{2,3} = 2(164 - 36 - 20) = 2(108) = \underline{216"}$
$L_{5-8} = 4(107 - 36 - 20) = 4(51) = \underline{204"}$
$L_{9-12} = 4(107 - 36 - 20) = 4(51) = \underline{204"}$

$L_{TOTAL} = L_{1-12} = \underline{864"}$

$t_{12"D} = \frac{FSxPR}{\sigma} = \frac{1.667 \times 375 \times 6}{65{,}000} = .058 \rightarrow \underline{.063 \pm .005}$

$t_{15"D\ \&\ DIFFUSERS} = \frac{1.667 \times 375 \times 7.5}{65{,}000} = .0722 \rightarrow \underline{.080 \pm .007}$

WEIGHT 12" FEED DUCTS

$W_{12} = \pi D L t \rho = \pi\ 12 \times 864 \times .063 \times .286 = \underline{587^*}$

WEIGHT 15" FEED DUCTS

$W_{12} = 12\pi D L t \rho = 12\pi\ 15 \times 56 \times .080 \times .286 = \underline{724^*}$

WEIGHT DIFFUSERS

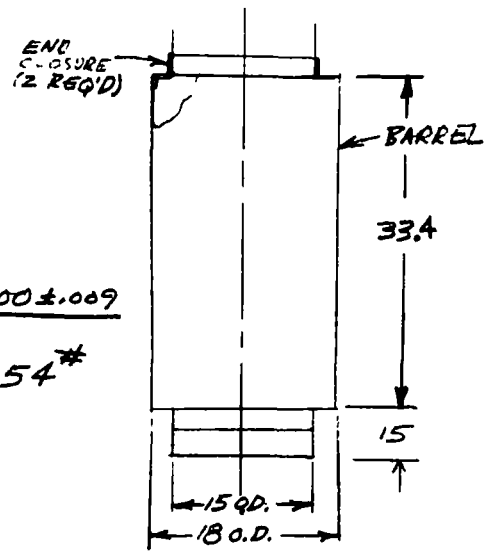
$W_{12} = 12\pi(R+r)\ell t \rho = 12\pi(6+7.5)17.1 \times .080 \times .286 = \underline{199^*}$

TOTAL WEIGHT = 1510*

POGO ACCUMULATORS

12 PLACES ON LOX FEED DUCTS AT ENGINE INLET

ARMCO 21-6-9



BARREL (12 REQ'D)

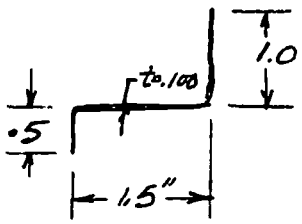
$t = \frac{FS)PR}{\sigma} = \frac{1.667 \times 375 \times 9}{65000} = .088 \sim .100 \pm .009$

$W_{EACH} = \pi D L t \rho = \pi 18 \times 33.4 \times .100 \times .286 = 54^{\#}$

$W_{12} = 12 \times 54^{\#} = \underline{648^{\#}}$

ENDCLOSURE (24 REQ'D-12 PAIRS)

$A = 3 \times .1 = .3 m^2$



$W_{EACH} = \pi D A \rho$

$W_{EACH} = \pi \times 16.4 \times .3 \times .286 = 4.42$

$W_{24} = 24 \times 4.42^{\#} = \underline{106^{\#}}$

TOTAL WEIGHT = 754#

LO_2 MANIFOLD

22" SEGMENTS

$L = 2(20+65+60+20) = 2(165) = 330"$

$t = \frac{FS \times PR}{\sigma_{YLD}} = \frac{1.667 \times 375 \times 11}{65{,}000} = .106 \sim .125 \pm .010$

$W = \pi DLt\rho = \pi 22 \times 330 \times .125 \times .286 = 814^{\#}$

13" SEGMENTS

$L = 2(95) = 190"$

$t = \frac{FS \times PR}{\sigma_{YLD}} = \frac{1.667 \times 375 \times 6.5}{65{,}000} = .0625 \sim .080 \pm .007$

$W = \pi DLt\rho = \pi 13 \times 190 \times .080 \times .286 = 177^{\#}$

8" SEGMENT

$L = 2(170) = 340$

$t = \frac{FS \times PR}{\sigma_{YLD}} = \frac{1.667 \times 375 \times 4}{65{,}000} = .0385 \rightarrow .045 \pm .005$

$W = \pi DLt\rho = \pi 8 \times 340 \times .045 \times .286 = 110^{\#}$

TOTAL WEIGHT	$1101^{\#}$

LO_2 MAIN DUCT ASSEMBLIES (P.)

(2, 22" DIA FROM STA 2020 TO STA 3553)

DESIGN PRESSURES

NO SURGE CONDITIONS FORWARD OF MANIFOLD

$P_{x1997} = 49.3$ PSI (APEX AFT DOME)

$P/\Delta h = \rho g h = 71\ ^{\#}/FT^3 \times 3G \times 1\frac{1}{6} = 213\ PSF/FT = .125\ PSI/IN$

$P_x = 49.3 + .125(X - 1997)$

$P_{2020} = 52.2$ PSI

$P_{2173} = 71.3$ PSI

$P_{3553} = 243.8$ PSI

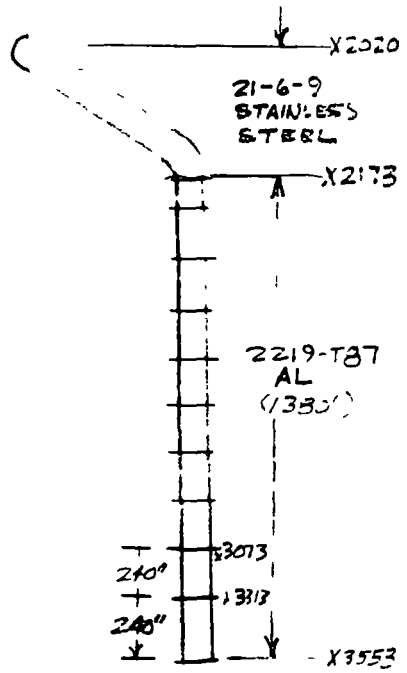
CONSTRUCTION

ALUMINUM DUCTING MUST BE CONSTRUCTED IN 240" SEGMENTS. SEGMENTS ARE JOINED BY A PAIR OF 15LB (PER PAIR) FLANGES.

$t_{MIN\ GAUGE\ STEEL} = .063 \pm .006$
$t_{MIN\ GAUGE\ ALUM} = .080 \pm .004$
} FOR 22"D

ALUMINUM DUCT JOINED TO STEEL BY 7.5# AL FLANGE TO 22# STL FLANGE AT EACH END.

TOTAL WEIGHT = $(2 \times 22 + 2 \times 7.5) \times 2$ DUCTS = 118#



2219-T87 AL

$\sigma_{ULT} = 63{,}000$ PSI
$\sigma_{YLD} = 52{,}000$ PSI
$E = 10.5 \times 10^6$ PSI
$\rho = .102\ LB/IN^3$

21-6-9 STAINLESS STL

$\sigma_{ULT} = 95{,}000$ PSI
$\sigma_{YLD} = 65{,}000$ PSI
$E = 28.5 \times 10^6$ PSI
$\rho = .286\ LB/IN^3$

LO_2 MAIN DUCTS (ρ_2)

STEEL DUCTS

$$t = \frac{FS \times P \times R}{\sigma_{YLD}} = \frac{1.667 \times 71.3 \times 11}{65{,}000} = .020 \quad t_{MIN\ GAUGE} = .063$$

(BOTH) $L = 2(60 + 150 + 100 + 30 - 5 \times 22) = 2(230) = 460$

$$W_2 = \pi D L t \rho = \pi 22 \times 460 \times .063 \times .286 = 573^{\#}$$

ALUMINUM DUCTS

STATION WHERE DUCT DESIGNED BY PRESSURE

$t_{MIN\ GAUGE} = .080 - .004 = .076$

$$t = \frac{SF_{YLD}\ PR}{\sigma_{YLD}} = \frac{1.667 \times PR}{52{,}000} = .32 \times 10^{-4} PR$$
$$t = \frac{SF_{ULT}\ PR}{\sigma_{ULT}} = \frac{2 \times PR}{63{,}000} = .318 \times 10^{-4} PR$$

$\therefore$ "t" IS DESIGNED BY YIELD CRITERIA

$$P = \frac{t\ \sigma_{YLD}}{R\ SF_{YLD}} = \frac{.076 \times 52{,}000}{11 \times 1.667} = 216\ PSI$$

$$\Delta X = \frac{\Delta P}{(\Delta P/\Delta X)} = \frac{243.8 - 216}{.125} = \frac{27.8}{.125} = 222''$$

$\therefore$ ONE BOTTOM 240" SEGMENT DESIGNED BY PRESSURE & REMAINING FIVE SEGMENTS (1140") BY MINIMUM GAUGE

MINIMUMUM GAUGE DUCTS

$$W_2 = 2\pi D L t \rho = 2\pi\ 22 \times 1140 \times .080 \times .102 = 1285^{\#}$$

AL TO AL ATTACH FLANGES

6 DUCT SEGMENTS PER DUCT → 5 PAIRS PER DUCT

$W = 10 \times 15^{\#} = 150^{\#}$

LO_2 MAIN DUCTS (φ3)

ALUMINUM DUCTS - CONTINUED

AFT DUCT SEGMENT

$$t = \frac{FS \times PR}{\sigma} = \frac{1.667 \times 243.8 \times 11}{52{,}000} = .0862 \rightarrow .092 \pm .005 \text{ (CHEM-MILLED)}$$

$$W_2 = \pi D L t \rho = 2\pi \times 240 \times .092 \times .102 = \underline{312\#}$$

WELD PENALTY

FOR SOLUTION REHEAT TREATED WELDS TYPICAL YIELD STRENGTHS ARE 52,000 PSI. 40,000 PSI WAS ARBITRARILY CHOSEN AS A MINIMUM VALUE. TOTAL WELD WIDTH IS 2"

$$P = \frac{t \sigma_{YLD}}{SF_{YLD} R} = \frac{.076 \times 40{,}000}{11 \times 1.667} = 166 \text{ PSI}$$

$$\Delta X = \frac{\Delta P}{(\Delta P/\Delta X)} = \frac{243.8 - 166}{.125} = \frac{77.8}{.125} = .624"$$

∴ THREE AFT 240" SEGMENTS MUST HAVE WELD BOSSES

AFT SEGMENT

$$t_{WELD} = \frac{SF \times PR}{\sigma} = \frac{1.667 \times 243.8 \times 11}{40{,}000} = .112 \rightarrow .117 \pm .005 \text{ (CHEM-MILLED)}$$

$$\Delta W_{WELD(1)} = 2(\Delta t) W L \rho = 2 \times (.117 - .092) 2 \times 240 \times .102 = \underline{25\#}$$

NEXT TO AFT SEGMENT

$$P = 243.8 - \Delta X \frac{\Delta P}{\Delta X} = 243.8 - 240 \times .125 = 243.8 - 30 = 213.8$$

$$t_{WELD} = \frac{SF \times PR}{\sigma} = \frac{1.667 \times 213.8 \times 11}{40{,}000} = .098 \rightarrow .103 \pm .005 \text{ CHEM-MILLED}$$

$$\Delta W_{WELD(2)} = 2(\Delta t) W L \rho = 2(.103 - .084) 2 \times 240 \times .102 = \underline{23\#}$$

2ND TO AFT SEGMENT

$$t_{WELD} = \frac{FS \times PR}{\sigma} = \frac{1.667 \times 183.8 \times 11}{40{,}000} = .084 \rightarrow .090 \pm .005 \text{ (CHEM-MILLED)}$$

$$\Delta W_{WELD(3)} = 2(\Delta t) W L \rho = 2(.090 - .084) 2 \times 240 \times .102 = \underline{10\#}$$

LO2 MAIN DUCTS (P4)

	WEIGHT (LB)
AL TO STEEL ATTACH FLANGES (2 PAIR)	118
STEEL DUCTS	573
ALUMINUM MINIMUM GAUGE DUCT	1285
ALUMINUM AFT DUCT SEGMENT	312
ALUMINUM WELD PENALTY	58
AL TO AL ATTACH FLANGES	150
TOTAL WEIGHT	2496#

LH_2 FEED DUCTS (ARMCO 21-6-9)

12, 12" DUCTS $L_{TOTAL} = 1202"$
12, DIFFUSERS $L = 17"$ EACH
12, 15" DUCTS $L_{TOTAL} = 56" \times 4 + 40" \times 8 = \underline{544"}$

12" DUCTS

$L_{i,j}$ L = length (in) ; i,j = engine numbers // -36" for 3 Bellows, -20" for Iso. Valve

$L_{1,4} = 2(45+105+40-36-20) = 2(134) = \underline{268}$
$L_{2,3} = 2(85+40-36-20) = 2(69) = \underline{138}$
$L_{5,8} = 2(105+60-36-20) = 2(109) = \underline{218}$
$L_{6,7} = 2(40+40+72-36-20) = 2(96) = \underline{192}$
$L_{9,12} = 2(35+110+40-36-20) = 2(129) = \underline{258}$
$L_{10,11} = 2(80+40-36-20) = 2(64) = \underline{128}$
$L_{TOTAL} = L_{1-12} = 1202$

$t_{12"D} = \frac{FS \times PR}{\sigma_{YIELD}} = \frac{1.667 \times 100 \times 6}{65{,}000} = .016$, $t_{MIN\ GAUGE} = \underline{.036}$

$t_{15"D}$ & DIFFUSER $= \underline{.040}$ (MIN. GAUGE)

WEIGHT 12" FEED DUCTS

$W_{12} = \pi D L t \rho = \pi 12 \times 1202 \times .036 \times .286 = \underline{467\#}$

WEIGHT 15" FEED DUCTS

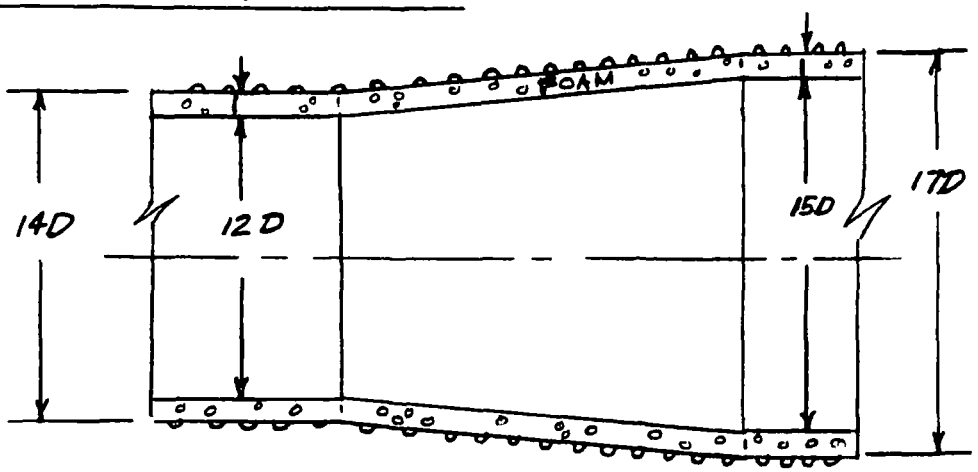
$W_{12} = \pi D L t \rho = \pi 15 \times 544 \times .040 \times .286 = \underline{293\#}$

WEIGHT DIFFUSERS

$W_{each} = \pi (r+R) \ell t \rho = \pi (6+7.5) 17.1 \times .040 \times .286 = 8.3\#$ EACH
$W_{12} = 12 \times 8.3\# = \underline{100\#}$

TOTAL WEIGHT = 860#

LH_2 DUCT INSULATION JACKETS



t_{JACKET} = 1.3 STIFFENING FACTOR X .016 SKIN THICKNESS = .0208

FOAM = 3#/FT³

JACKET – 12" LINES

$W_{12} = \pi D L t \rho = \pi 14 \times 1202 \times .0208 \times .286 =$ **314#**

JACKET – DIFFUSERS

$W_{12} = 12\pi D l t \rho = 12\pi 15.5 \times 17.1 \times .0208 \times .286 =$ **59#**

JACKET – 15" LINES

$W_{12} = \pi D L t \rho = \pi 17 \times 544 \times .0208 \times .286 =$ **173#**

FOAM – 12" LINES

$W_{12} = \pi D L t \rho = \pi 13 \times 1202 \times 1 \times \frac{3}{1728} =$ **85#**

FOAM – DIFFUSERS

$W_{12} = 12\pi D l t \rho = 12\pi 14.5 \times 17.1 \times 1 \times \frac{3}{1728} =$ **16#**

FOAM – 15" LINES

$W_{12} = \pi D L t \rho = \pi 16 \times 544 \times 1 \times \frac{3}{1728} =$ **48#**

TOTAL WEIGHT = 695#

7. CRUISE PROPULSION	37053		
ENGINE & ACCESSORIES	[28084]	WEIGHT (LB)	PAGE NO.
ENGINES		(26140)	2.7-4
LEVEL SENSING		(130)	2.7-6
CAPACITANCE PROBES		72	
ELECTRONICS PACKAGE		6	
POINT LEVEL SENSORS		2	
WIRING		42	
SUPPORT		8	
ACCESSORIES		(1814)	2.7-7
INSTRUMENTATION		390	2.7-7
FIRE DETECTION & EXTINGUISHING		210	2.7-7
STARTING SYSTEM		1214	2.7-8
INSTALLATION, DUCTS SHROUDS	[3893]		2.7-10
AIR INDUCTION		(1108)	2.7-12
ENGINE MOUNTING		(195)	2.7-16
FIREWALLS		(990)	2.7-23
EXHAUST SYSTEM		(1600)	2.7-19
PROPELLANT SYSTEM	[1428]		2.7-24
FILL, DRAIN & DUMP		(139)	2.7-39
FILL & DRAIN VALVES & DISCONNECT		27	
DUMP VALVES		14	
LINES & FITTINGS		56	
SUPPORTS		8	
FUEL JETTISON CIRCUITRY & CONTROLS		34	

(CRUISE PROPULSION - CONTINUED)

ITEM		WEIGHT (LB)	PAGE NO.
PRESSURIZATION & VENT		(246)	2.7-35
PRESSURIZATION VALVES & XDUCERS		103	
VENT VALVES		42	
VENT BOXES		25	
CIRCUITRY		20	
LINES & FITTINGS		28	
SUPPORTS		28	
BLEED AIR SUPPLY		(46)	2.7-41
VALVES		20	
LINES & FITTINGS		23	
SUPPORTS		3	
PNEUMATIC ACTUATION		(111)	2.7-40
VALVES		86	
LINES & FITTINGS		12	
SUPPORTS		13	
FEED & TRANSFER		(886)	2.7-31
VALVES		168	
PUMPS		180	
LINES & FITTINGS		360	
CIRCUITRY		105	
SUPPORTS & INSTALLATION		73	
TANKAGE-NON INTEGRAL	[2656]		2.7-42
FORWARD TANKS		(1492)	2.7-42
WING TANKS		(1164)	2.7-45
CONTINGENCY	[992]		2.7-46

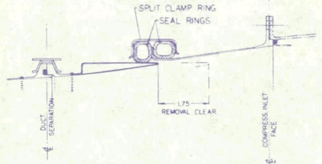
7. PROPULSION – CRUISE BACK					37053
ENGINE & ACCESSORIES					28084
ENGINE				26140	
LEVEL SENSING				130	
LUBRICATION SY (DRY)				—	
ACCESSORIES				1814	
INSTALLATION, DUCTS, SHROUD					3893
AIR INDUCTION				1108	
ENGINE MOUNTING				195	
FIREWALLS				990	
EXHAUST SY				1600	
PROPELLANT SY					1428
FILL DRAIN & DUMP				139	
PRESSURIZATION (DRY) & VENT				246	
BLEED AIR SUPPLY				46	
PNEUMATIC ACTUATION				111	
FEED SY & TRANSFER				886	
TRANSFER SY				—	
DUMP SY				—	
SUPPORTS/INSTALLATION				—	
TANKAGE – NON INTEGRAL	TANK	INSULATE	SUPTS		2656
FUEL					
CONTINGENCY					992

CRUISE ENGINES

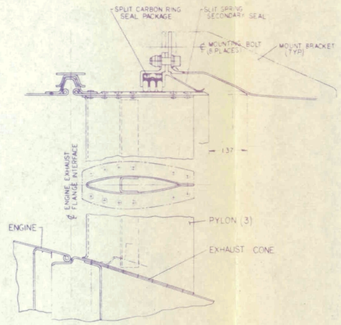
TEN GE F101/F12B-3 ENGINES

WEIGHT EACH = 2614 LB

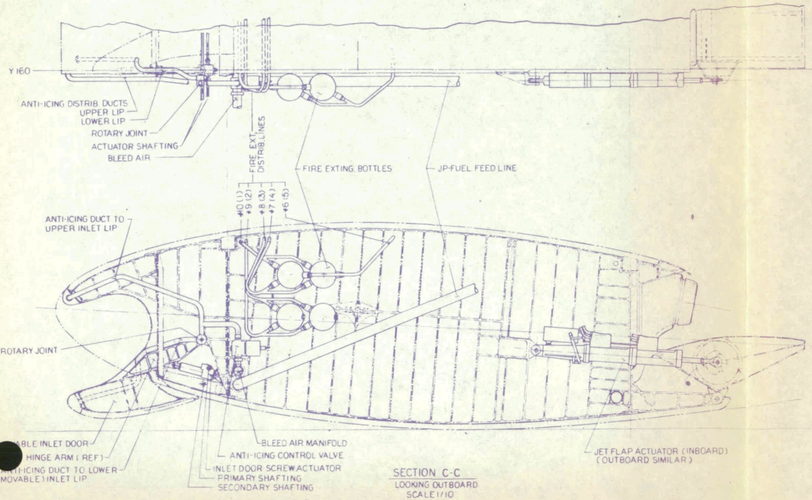
WEIGHT TEN = 26,140 LB



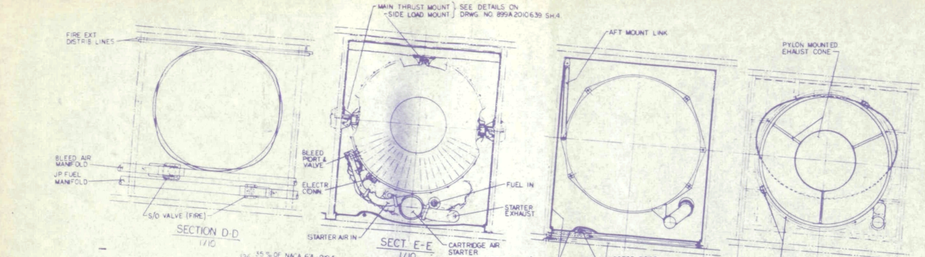
DETAIL H
FULL SCALE
INLET FLEX JOINT



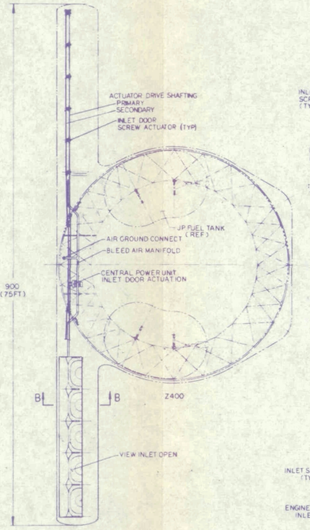
DETAIL J
FULL SCALE
EXHAUST DUCT FLEX SEAL



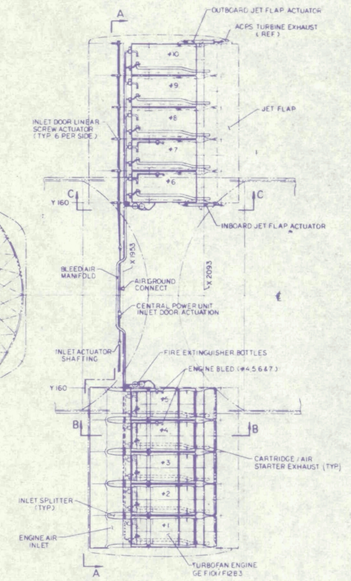
SECTION C-C
LOOKING OUTBOARD
SCALE 1/10



BOTTOM VIEW
SCALE 1/10



SECTION A-A
LOOKING AFT
SCALE 1/50



PLAN VIEW
LOOKING DOWN
SCALE 1/50

M.S. WINTER 6-11-71

AIRBREATHING ENGINGE INSTALLATION

899A2020650

PROPELLANT LEVEL SENSING - CRUISE PROPULSION

END KIDNEY TANKS

TWELVE CAP. PROBES @ 4 LB/SENSOR	48.0
ELECTRONICS PACKAGE	2.5
SUPPORT (10 %)	5.0
WIRING (INCLUDES SUPPORT)	12.0
	67.5

WING TANKS

TWELVE CAP PROBES @ 2 LB/SENSOR	24.0
ELECTRONICS PACKAGE	3.5
TWELVE POINT LEVEL SENSORS @ 125 LB EA	1.5
SUPPORT (10 %)	2.9
WIRING (INCLUDES SUPPORT)	30.0
	61.9

TOTAL 130

CRUISE ACCESSORIES

ISTRUMENTATION

FIVE DISCREETS (POSITION INDICATORS) 0.3LB EACH	1.5
THIRTY SENSORS (PRESSURE, TEMP. ETC.) 1.25LB EACH	37.5
WEIGHT (INCL. WIRING) PER ENGINE	39
WEIGHT FOR TEN ENGINES	390 LB

FIRE DETECTION AND EXTINGUISHING

BOTTLES (4@11# & 4@12# - because of extra boss. BASED ON DC-10 WEIGHTS)	92
TUBING (2500" TOTAL @ 0.19 LB/FT)	39
BOTTLE SUPPORT (10% OF BOTTLE WEIGHT)	9
ELECTRICAL (WIRING, CONNECTORS & SWITCHES)	20
DETECTION (5 LB/ENGINE FOR CONTINUOUS WIRE SENSORS)	50
	210 LB

CRUISE ACCESSORIES
STARTING SYSTEM

CARTRIDGE/BLEED STARTER SYSTEM	990
BLEED AIR MANIFOLD	47
ENGINE BLEED	90
FIREWALL BLEED SHUTOFF INSTALLATION	80
GROUND START PROVISIONS	7
TOTAL STARTING SYSTEM	1214 LB

CARTRIDGE/BLEED STARTER SYSTEM

STARTER (BASED ON SUNSTRAND CPS-09)	80
SHUTOFF VALVE (2½" DIA)	4
EXHAUST TUBE (4" DIA LINE, 11')	12
INLET TUBE	1
ELECTRICAL	2
WEIGHT PER ENGINE	99
WEIGHT FOR 10 ENGINES	990 LB

BLEED AIR MANIFOLD

ENGINE 1-5 (220" OF 2½" D @ 0.5 LB/FT + 25% INSTALLATION)	12
CROSS OVER 5-6 (390" OF 3" D @ 0.54 LB/FT + 25% INSTALLATION)	23
ENGINE 6-10 (220" OF 2½" D @ 0.5 LB/FT + 25% INSTALLATION)	12
TOTAL WEIGHT	47 LB

STARTING SYSTEM - CONTINUED

ENGINE BLEED

SHUT-OFF VALVE (2½"D)	4
ATTACH FLANGE	2
LINE TO FIREWALL	2
ELECTRICAL	1
WEIGHT PER ENGINE	9
WEIGHT FOR 10 ENGINES	90 LB

FIREWALL BLEED SHUT-OFF INSTALLATION

SHUT-OFF VALVE (2½"D)	4
LINE TO MANIFOLD (12" OF 2½"D @ .5 $\frac{LB}{FT}$ + 25% INST.)	1
TEE AT MANIFOLD	2
ELECTRICAL	1
WEIGHT PER ENGINE	8
WEIGHT FOR 10 ENGINES	80LB

GROUND START PROVISIONS

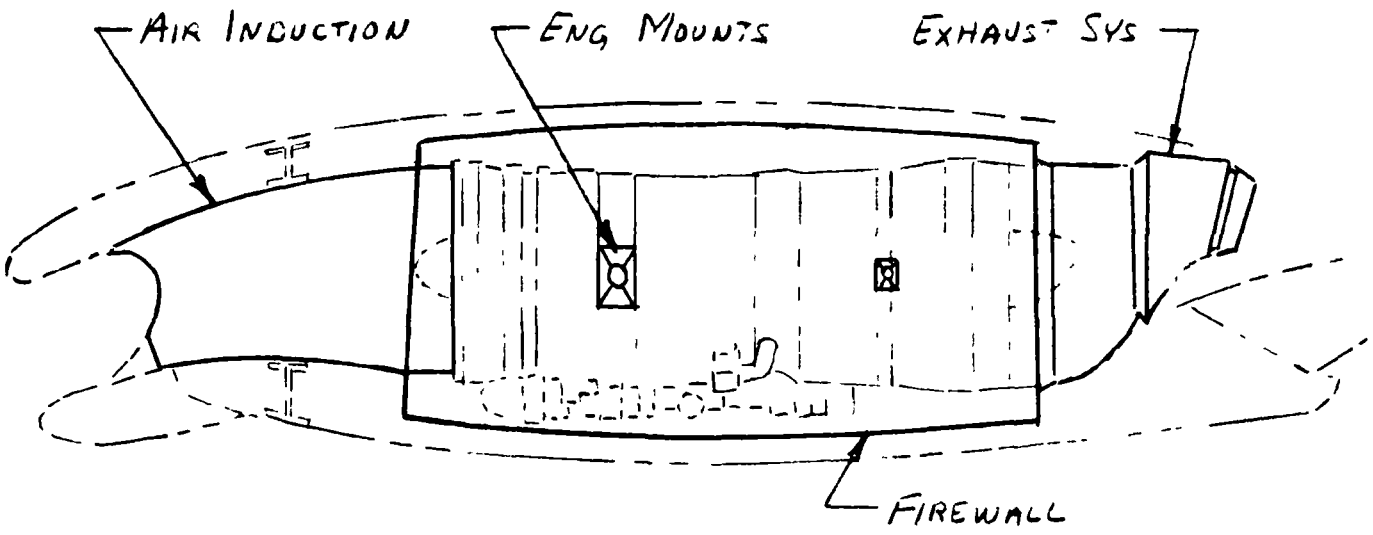
DOOR	2
ADAPTER	2
MECH. VALVE	2
TUBE	1
TOTAL WEIGHT	7 LB

PROPULSION - CRUISE BACK

INSTALLATION, DUCTS, SHROUD TOTAL 3893

	WEIGHT
AIR INDUCTION	[1108]
STRUCTURE AND MECHANISM	504
INLET DUCT	320
INLET FLEX SEAL	210
POWER UNIT, GEAR BOX & SUPT	74
ENGINE MOUNTING	[195]
FITTING	81
TRUNNION SHAFT	34
ACTUATOR	10
ATTACHMENTS	37
CANARD RTN BACK-UP	33
EXHAUST SYSTEM	[1600]
FORWARD SECTION	400
AFT ASSY	580
INNER CONE AND STRUTS	110
SEAL	510
FIREWALL	[990]
SHIELD	460
SPRAY-ON ABLATOR	480
ATTACHMENTS	50

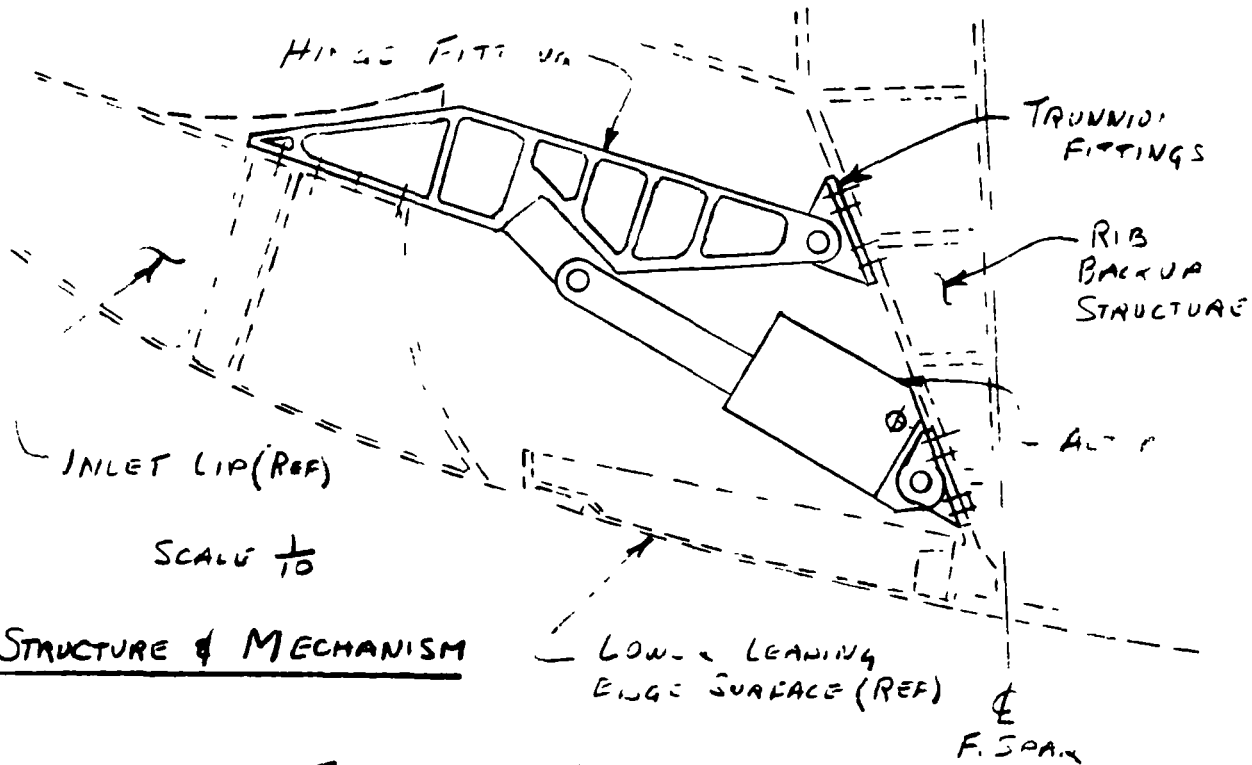
ABES INSTALLATION



INSTALLATION, DUCTS, SHROUD		3893
AIR INDUCTION	1108	
ENGINE MOUNTING	195	
FIREWALL	990	
EXHAUST SY	1600	

AIR INDUCTION SYSTEM SUMMARY

STRUCTURAL BACK-UP AND MECHANISM	12 @ 42#	504
INLET DUCT	10 @ 32#	320
INLET DUCT FLEX SEAL	10 @ 21#	210
PWR UNIT & SUPT (EST/EEMCO)		74
TOTAL		1108



STRUCTURE & MECHANISM

HINGE FITTING AL AL
WT = 93.2 IN^3 X .101 = 9.4

TRUNNION FITTING AL AL FORGE
WT: (6 x 6 x .5 + 6 x 3 x .5) 2 x .101 = 5.4

ACTUATOR WORM SCREW LINEAR TYPE
SUPPLIED BY EEMCO = 20.0

TORQUE TUBE 2.0 IN DIA X .050 ST
.0853 #/IN X 55 IN BETWEEN BAYS
WT = .0853 X 55 = 4.6

ATTACHMENTS
BOLTS 24 (.009 + .008) = .4
PIN 3 X .055 = .2
.6

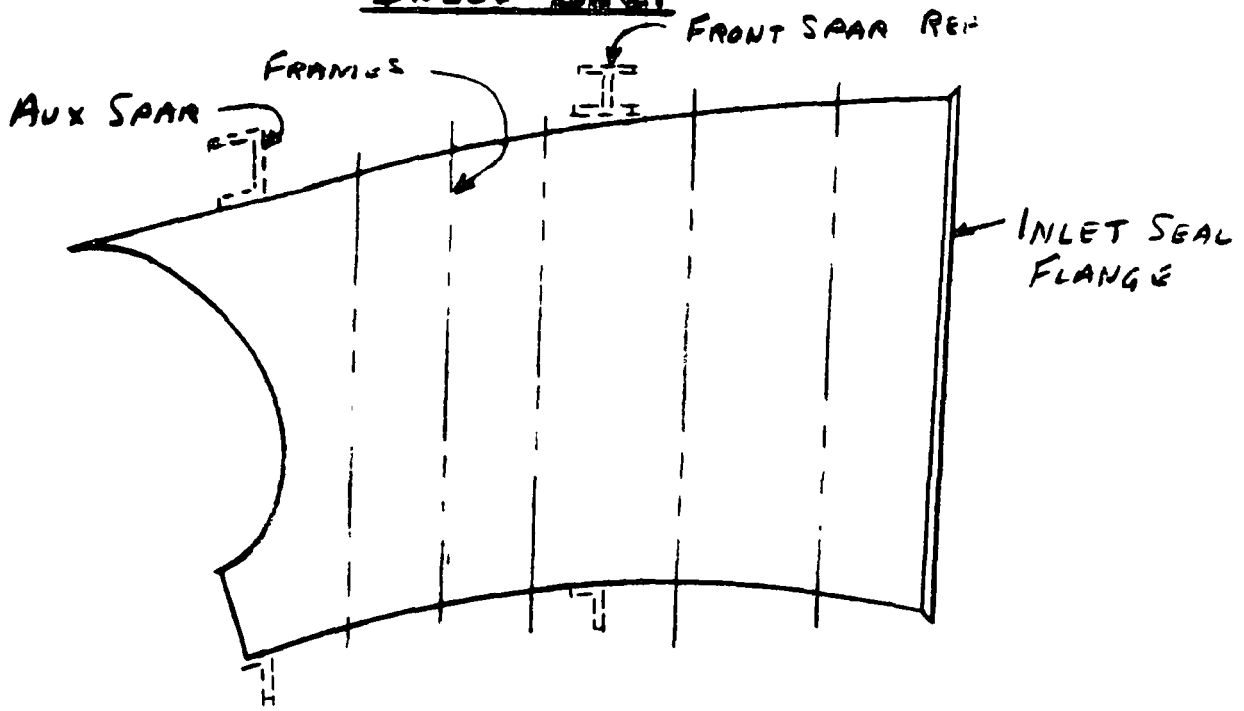
CONTINGENCY 5% 1.8

42.0

TOTAL FOR 12 504 LB

DEN 046037 (3-67)

INLET DUCT



SKIN AREA = 6640 IN^2 .032 AL

WT = 6640 X .032 X .101 = 21.4

FRAMES .032 AL 5 REQ

WT = 32π 5.0 X .032 X 5 X .101 = 8.0

ATTACHMENTS EST 5% 1.4

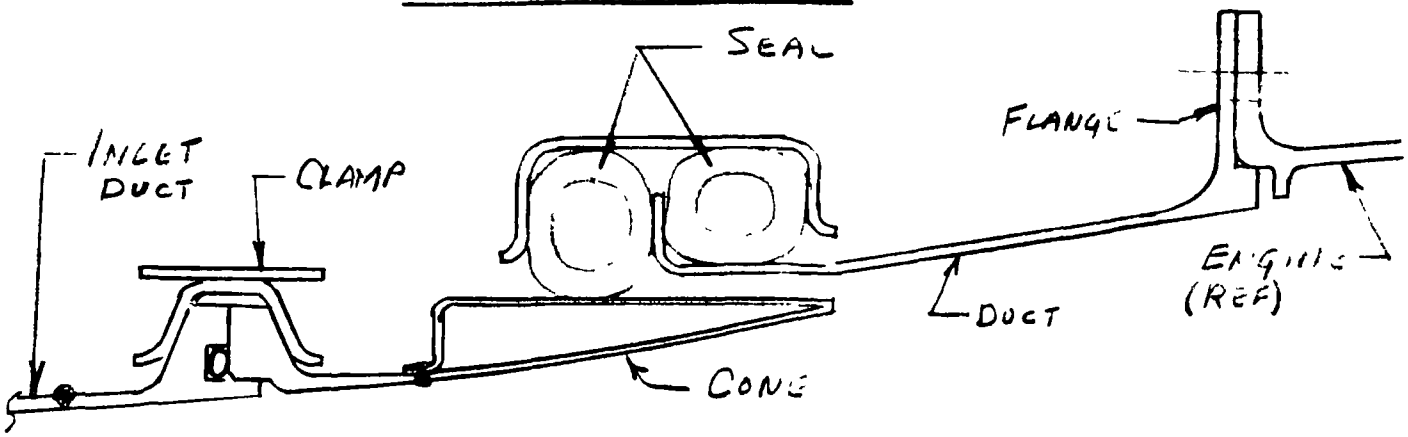
CONTINGENCY 5% 1.5

32.0

TOTAL FOR 10 320 LB

DEN 000007 (8-67)

INLET FLEX SEAL



SEAL 2 REQ .011 LB/IN

W/T = 45 π .011 x 2 = 3.1

SEAL RING .030 Ti

W/T = 2.25 x 45 π .030 x .165 = 1.6

CONE .030 Ti

W/T = 44 π 7.0 x .030 x .165 = 4.8

DUCT .030 Ti

W/T = 45 π 4.0 x .030 x .165 = 2.8

FLANGE

W/T = 46 π .1 x 1.25 x .165 = 3.0

FASTENERS 48 AN3

W/T = 48 (.009 + .008) = .8

CLAMP .030 ST

W/T = 44 π 2.5 x .030 x .3 = 3.0

21.0

TOTAL FOR 10 210 LB

POWER UNIT

POWER UNIT, GEAR BOX AND SUPT
SUPPLIED BY EEMCO
LOS ANGELES CAL. 74 LB

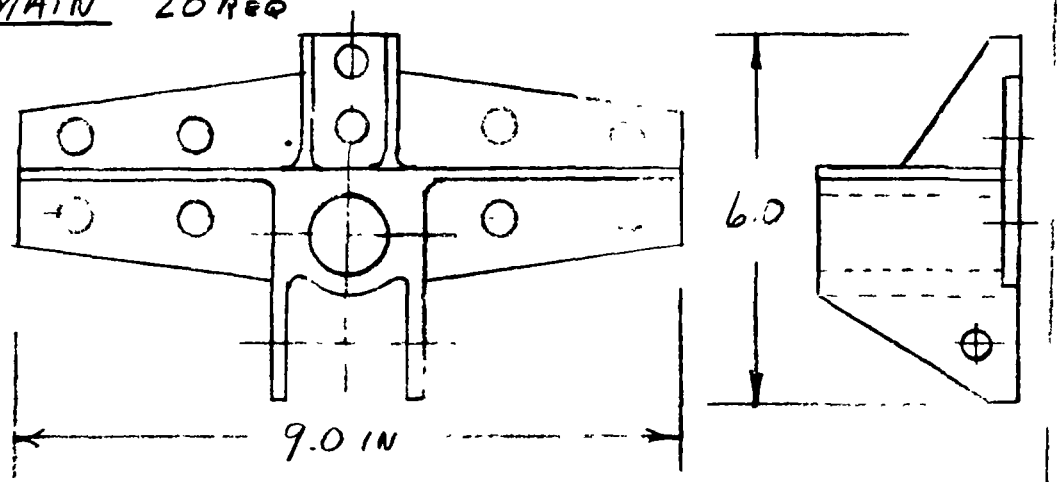
DEN 08037 (3-57)

CRUISE ENGINE MOUNT SUMMARY

FITTINGS		81
MAIN	44	
UPPER	11	
AFT	26	
TRUNNION		34
ACTUATOR		10
ATTACHMENTS -		37
- FWD	32	
- UPPER	3	
- AFT	2	
CANARD RIB BACK-UP		33
TOTAL		195 LB

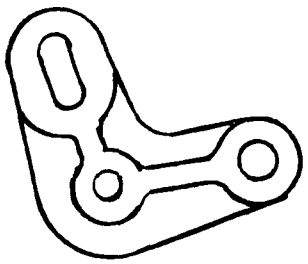
ENGINE MOUNT FITTINGS FWD

MAIN 20 REQ



WT = 21.7 IN^3 X .101 X 20 = 44 LB RIB

ACTUATOR 20 REQ



WT = 5.2 IN^2 X .101 X 20 = 10 LB

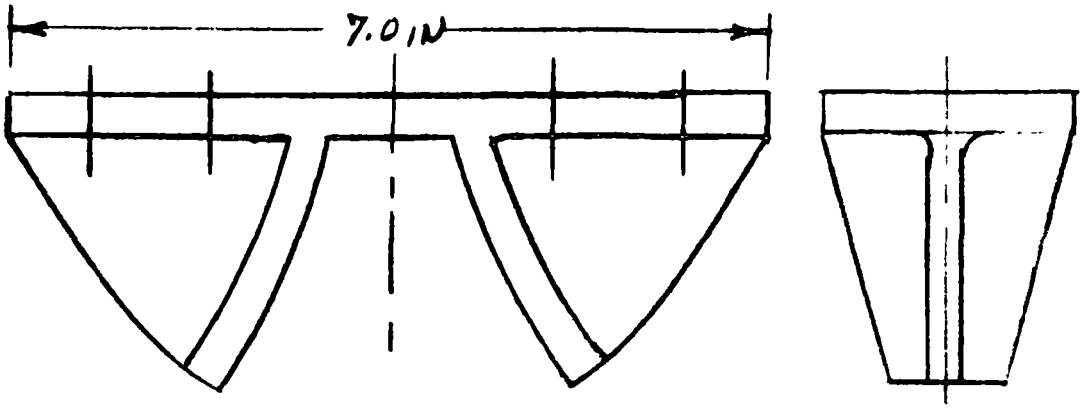
ATTACHMENTS

WT = (12 X 128 + 1 X .08) 20 = 32 LB

TRUNNION - SHAFT 2.0 X 4.25 ST

WT = 3.14 - 1.76 X 4.25 X .29 X 20 = 34 LB

ENGINE MOUNT FITTING UPPER

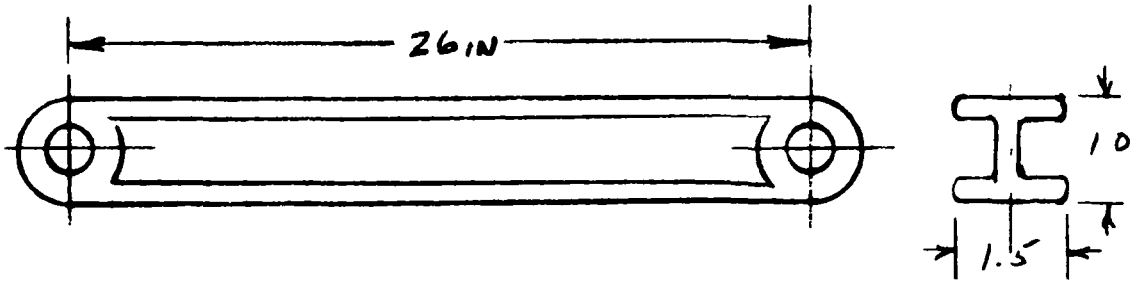


$WT = 11.1\ IN^3 \times .101 \times 10 =$ 11 LB

ATTACHMENTS

$WT = 8(.035 + .005)\ 10 =$ 3 LB

ENGINE MOUNT FITTING AFT



$WT = 25.6\ IN^3 \times .101 \times 10 =$ 26 LB

ATTACHMENTS

$WT = 2 \times (.06 + .02)\ 10 =$ 2 LB

CANARD RIB BACK-UP

FWD – $WT = 22.3\ IN^3 \times .101 \times 12 = 26.7$

AFT – $WT = 5.7\ IN^3 \times .101 \times 12 = 6.9$

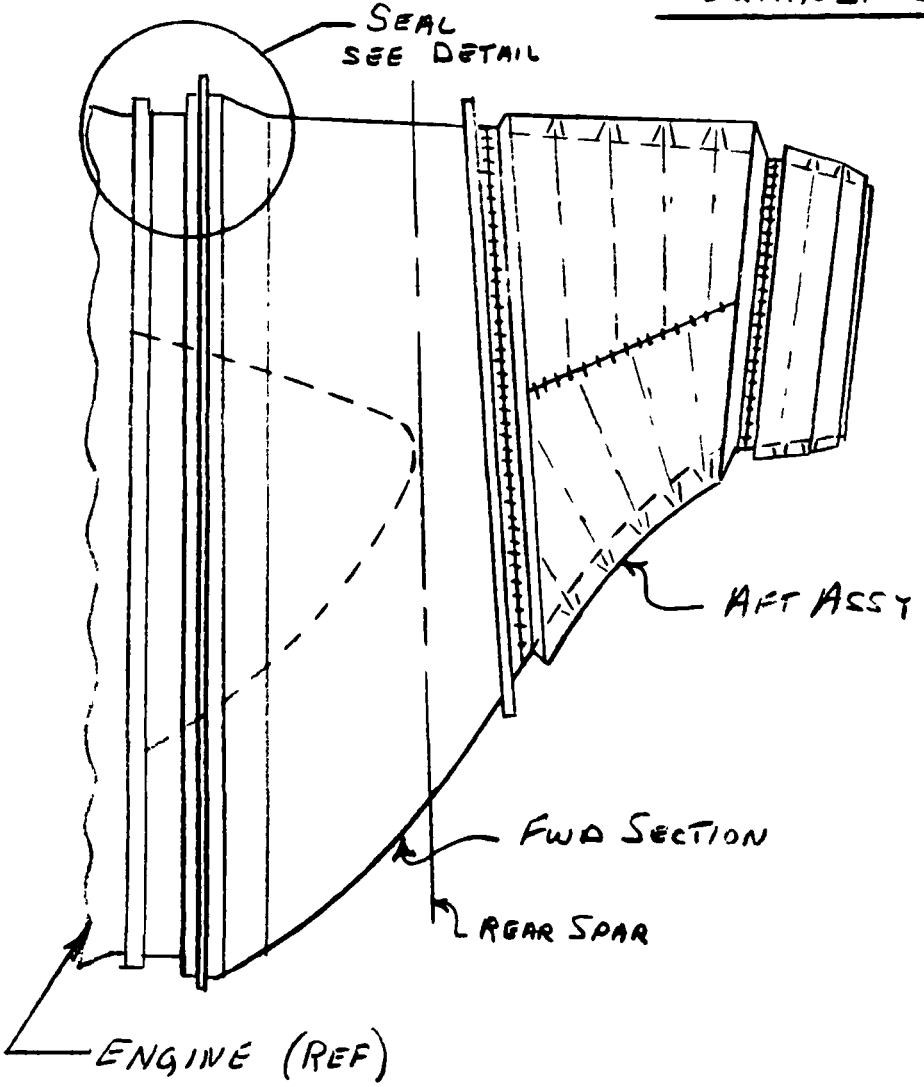
33 LB

DEN 000037 (2-87)

EXHAUST SYSTEM SUMMARY

FORWARD SECTION	400
AFT ASSY	580
INNER CONE AND STAYS	110
SEAL	510
TOTAL	1600 LB

EXHAUST SYSTEM



FORWARD SECTION

SKIN .050 SS AREA = 1960 IN²

W/T = 1760 X .050 X .290 — 25.6

FRAME SS @ AFT SPAR

W/T = 36 π 2 X .100 X .290 — 6.6

AFT FRAME SS

W/T = 32 π 2 X .100 X .290 — 5.8

CONTINGENCY 5% — 1.9

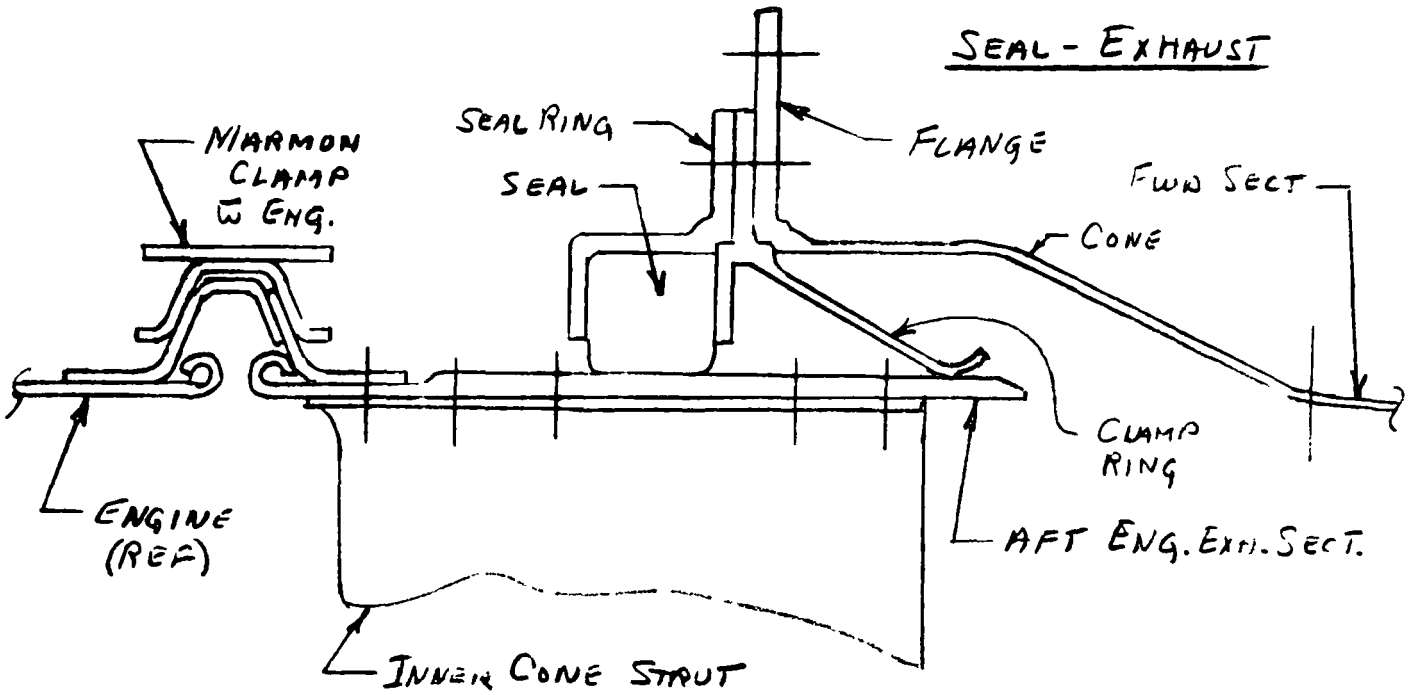
TOTAL — 40LB

AFT ASST

SKIN .030 SS AREA = 2520 IN^2		
WT = 2520 x .030 x .290 =		22.0
JACKET .030 SS AREA = 2840 IN^2		
WT = 2840 x .030 x .290 =		24.7
STIFFENERS 5 REQ .015 SS		
AREA = 125 x 3.0 x 5 = 1875		
WT = 1875 x .015 x .290 =		8.2
CONTINGENCY 5%		2.8
TOTAL		58 LB

INNER CONE AND STRUTS

CONE .038 SS		
AREA = 20 π/2 x 16 = 500		
WT = 500 x .038 x .290 =		5.5
STRUTS .030 SS		
AREA = 7.5 x 12 x 4 = 358		
WT = 358 x .030 x .290 =		3.1
ATTACHMENTS 96 AN3 + AN15		
WT = 96 (.009 + .005) =		1.3
CONTINGENCY 5%		.5
TOTAL		11 LB



SEAL (CARBON)

WT = .6 x .6 x 44 π x .15 = 7.5

AFT ENGINE EXHAUST SECTION SS

WT = .1 x 44 π x .290 = 19.2

SEAL RING Ti

WT = 1.3 x .15 x 45.5 π x .165 = 4.6

CLAMP RING Ti

WT = (1.3 x .1 x 44.5 π + 1.4 x .05 x 43 π) .165 = 4.6

FLANGE SS

WT = 1.5 x .08 x 47 π x .290 = 5.2

CONE SS

WT = 2.8 x .045 x 46 π x .290 = 5.3

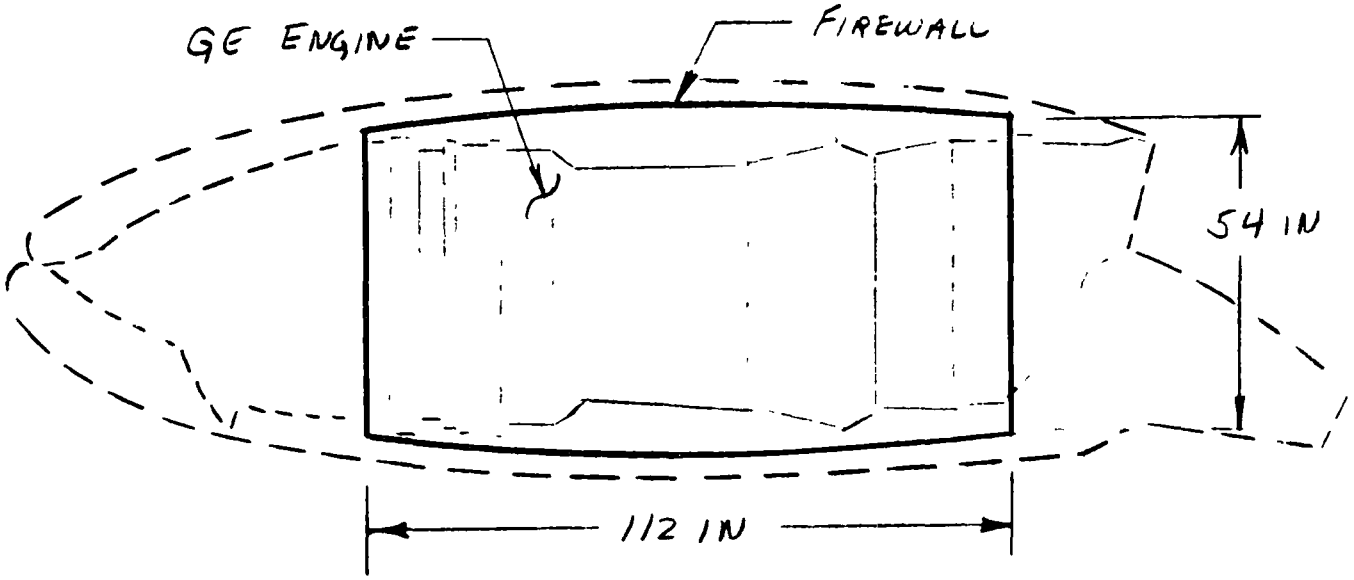
ATTACHMENTS 78 AN6 + AN316

WT = 78 (.042 + .010) 4.1

TOTAL 51 LB

8.7-22

FIREWALL



ENGINE COMPLETELY ENCLOSED IN .010 TITANIUM WITH SPRAY ON ABLATOR .040 THICK.
EACH BAY IS 53 IN WIDE

SHIELD .010 Ti

AREA = $112 \times 54 \times 2 + 112 \times 53 \times 2 + (54 \times 53 - \pi 43^2/4)2$

= 26786 IN^2

WT = $26786 \times .165$ = 44

CORNER ANGLE 1 X 1 X .020

WT = $112 \times 2 \times .020 \times 2 \times .165$ = 2

SPRAY ON ABLATOR $\rho = .045$ LB/IN^3

WT = $26786 \times .040 \times .045$ = 48

FASTENERS 5 % 5

99

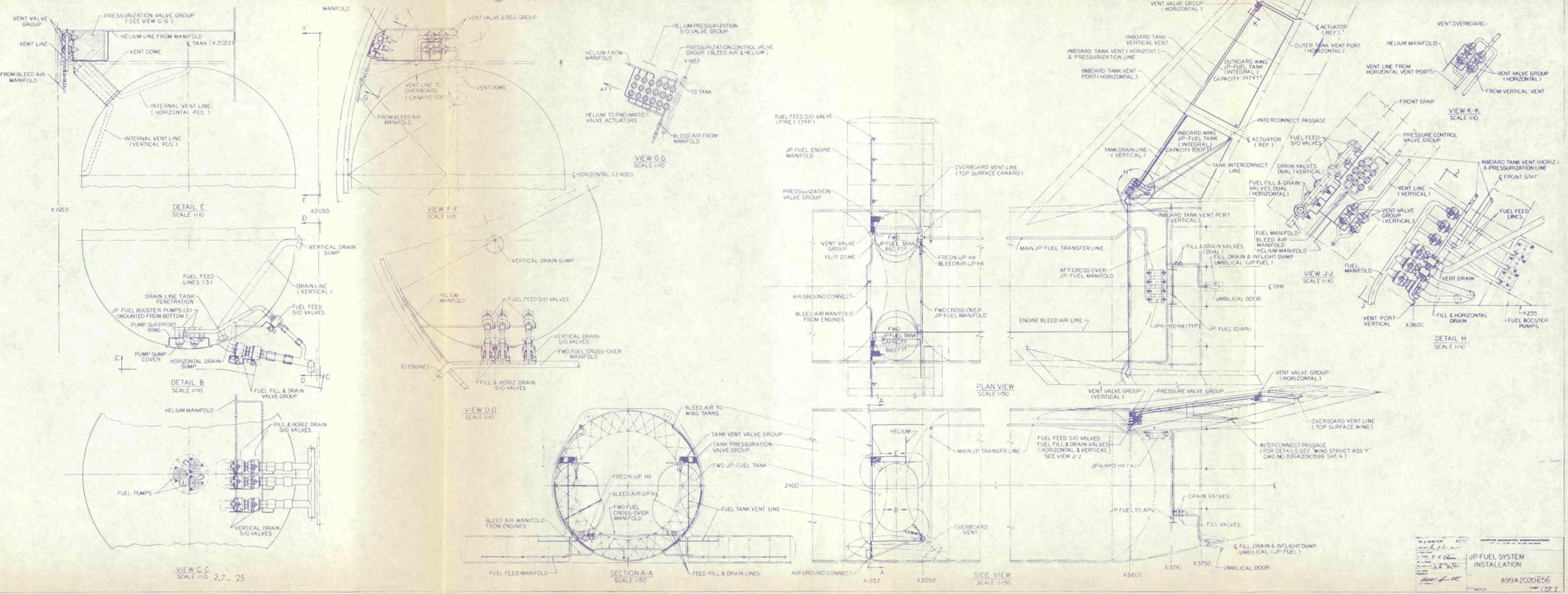
TOTAL FOR 10 990 LB

CONFIGURATION 20

(P 1A)

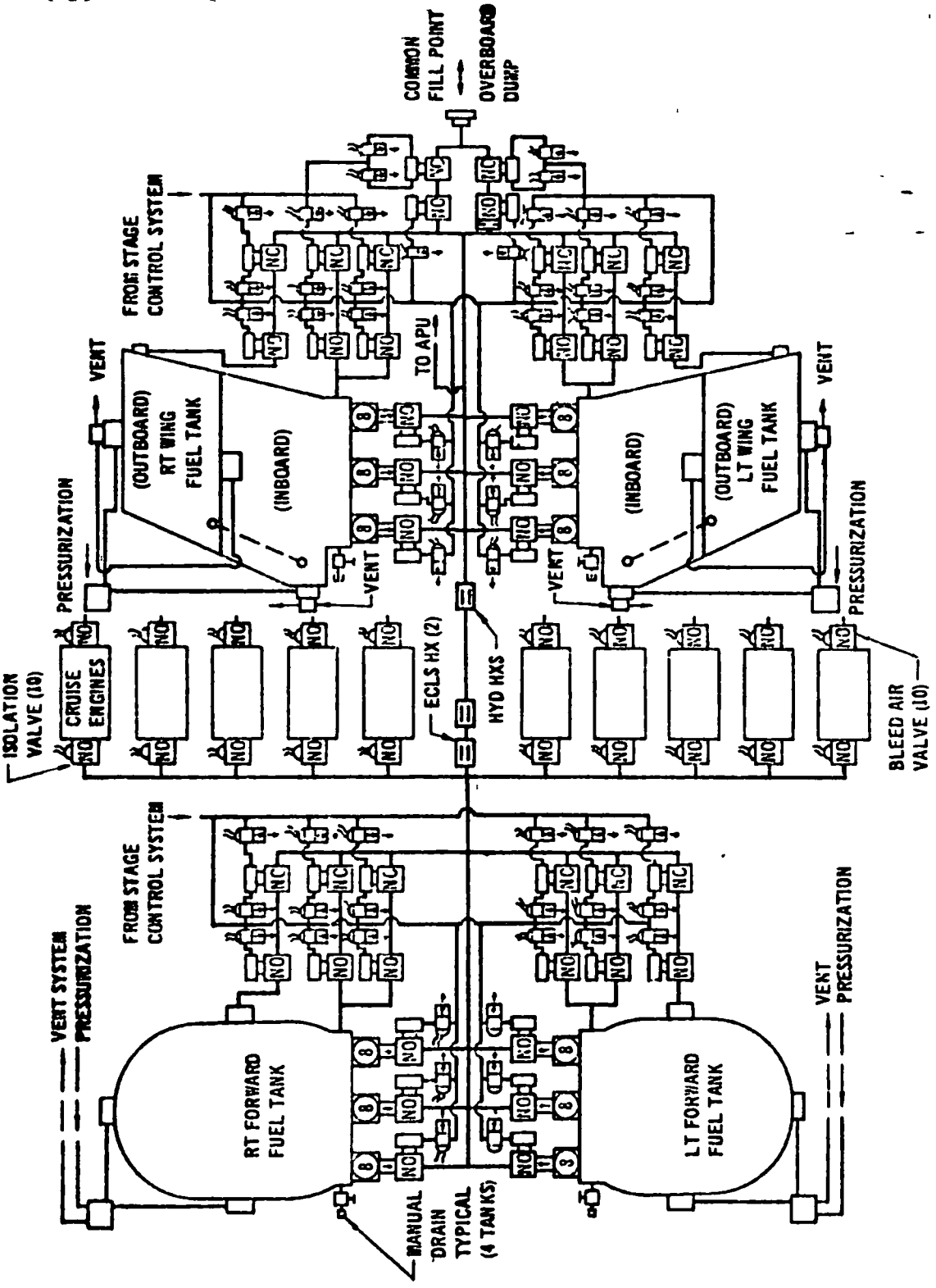
CRUISE PROPULSION SUBSYSTEMS

FEED & TRANSFER	886
PRESSURIZATION & VENT	246
FILL, DRAIN & DUMP	139
PNEUMATIC ACTUATION CONTROL	111
BLEED AIR SUPPLY	46
TOTAL	1428



DRAWN		MARTIN MARIETTA CORPORATION
CHECKED		JP-FUEL SYSTEM INSTALLATION
APPROVED		899A2020656
		SHEET 1 OF 2

CRUISE ENGINE FUEL SUPPLY SYSTEM



P/D-

1.3.6 Cruise Engine Fuel Supply System LRU's (Figures 1.3.6.1 & 1.3.6.2)

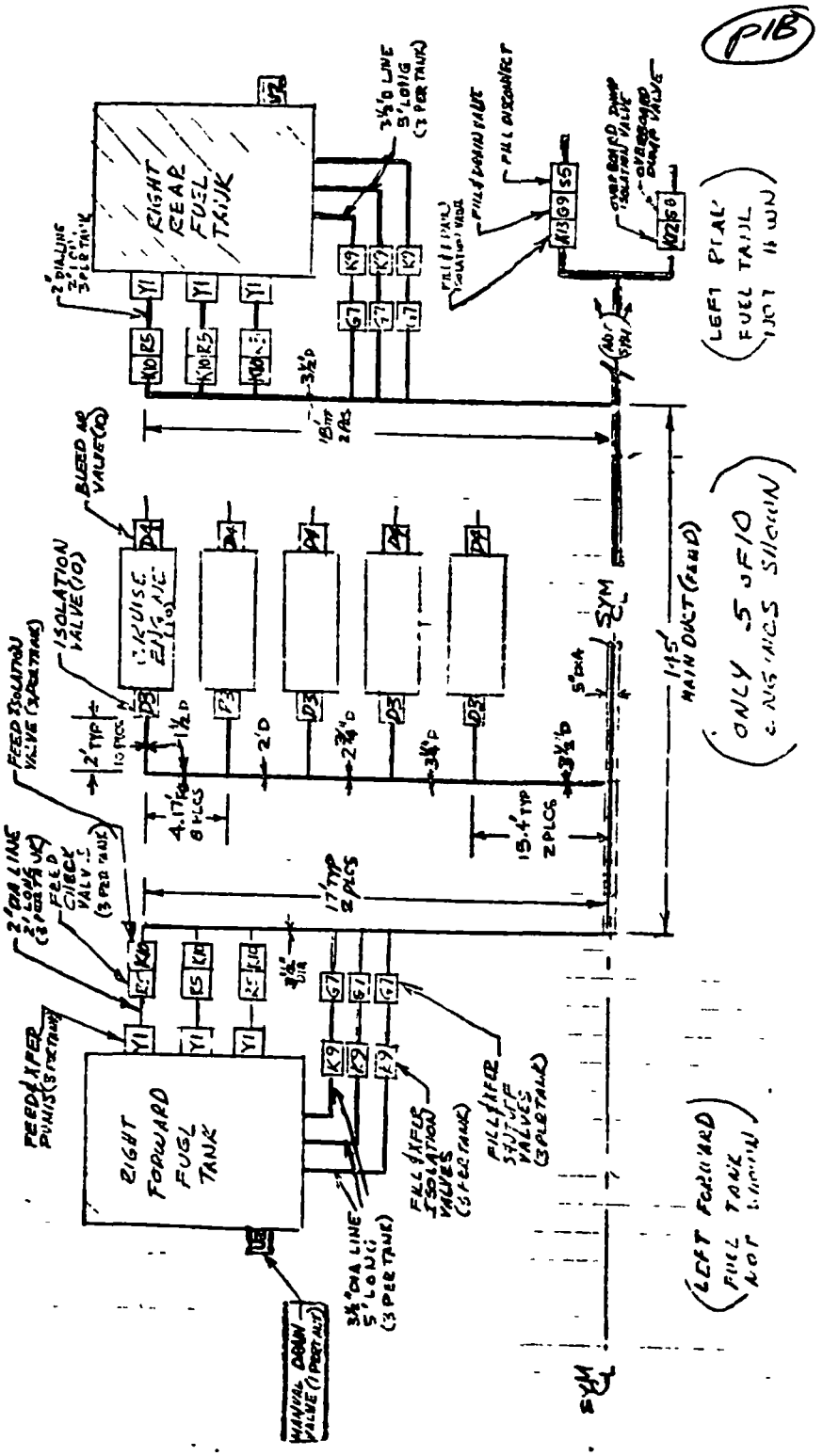
1. C4 - JP-4 Pressurization Control Solenoid Valves, 1/2 to 3/4 inch, pressure transducer controlled, 150 psia maximum operating pressure, 24 required (6 per tank) 1.2 EACH
2. C5 - Helium Supply Shutoff Solenoid Valves, 1/4 inch, 4600 psia maximum operating pressure, 12 required (6 each foward tank) 1.2 EACH
3. D3 - Engine Feed Isolation Solenoid Valves, 1 1/2 inch, 150 psia maximum operating pressure, 10 required (1 per engine) 2.4 EACH
4. D4 - Bleed Air Isolation Solenoid Valves, TBD inch, TBD psia maximum operating pressure, 10 required (1 per engine) (2.0 EACH) 1 W/ ENGINE
5. D5 - JP-4 Pressurization Control Isolation Solenoid Valve, 1/2 to 3/4 inch, 150 psia maximum operating pressure, 12 required (3 per tank) 2.0 EACH
6. D6 - Helium Supply Isolation Solenoid Valves, 1/4 inch, 4600 psia maximum operating pressure, 6 required (3 each foward tank) 1.2 EACH
7. G7 - Fill & Transfer Shutoff Valves, 3 1/2 inch, 150 psia maximum operating pressure, 12 required (3 per tank) 4.2 EACH
8. G8 - JP-4 Overboard Dump Valve, 5 inch, 150 psia maximum operating pressure, one required 7.4 LB
9. G9 - JP-4 Fill & Drain Valve, 5 inch, 150 psia maximum operating pressure, one required 7.4 LB
10. K9 - Fill & Transfer Isolation Valves, 3 1/2 inch, 150 psia maximum operating pressure, 12 required (3 per tank) 3.8 EACH
11. K10 - Feed Isolation Valves, 2 inch, 150 psia maximum operating pressure, 12 required (3 per tank) 2.8 EACH
12. K11 - Vent Isolation Valve, 2 inch, 25 psia maximum operating pressure, 8 required (2 per tank) 2.8 EACH
13. K12 - Overboard Dump Isolation Valve, 5 inch, 150 psia maximum operating pressure, one required 7.0 LB
14. K13 - Fill & Drain Isolation Valve, 5 inch, 150 psia maximum operating pressure, one required 7.0 LB
15. L3 - Vent & Relief Valve, 2 inch, 25 psia maximum operating pressure, 8 required (2 per tank) 3.2 EACH
16. Q7 - Bleed Air Check Valve, 3/4 inch, 150 psia maximum operating pressure, 8 required (2 per tank) 0.8 EACH
17. P5 - Feed Check Valves, 2 inch, 150 psia maximum operating pressure, 12 required (3 per tank) 1.4 EACH

(PIE)

18. S5 - Fill disconnect, 5 inch, 75 psia maximum operating presssure, one required 3.0 LB

19. U2 - Manual Drain Valve, 2 inch, 25 psia maximum operating pressure, 4 required (one per tank) Valve + Fitting 2.4 LBS EACH

20. Y1 - Feed and Transfer Pumps, 15 pps at 23 psid, 75 psia maximum pressure, 12 required (3 per tank) 15 LBS.



PROPELLANT SYSTEM

PROPELLANT SYSTEM WEIGHT FACTORS

LINE FITTINGS 30% LINE WEIGHT
(REF. DC-8 31%)
(REF. DC-9 30%)
(REF C-133 30%)

LINE SUPPORTS 18% LINE WEIGHT
(REF. DC-8 18%)
(REF DC-9 17%)
(REF C-133 17%)

FUEL PUMP INSTALLATION 13% PUMP WEIGHT
(REF DC-8 12.7%)
(REF DC-9 13.0%)

(PIF)

CRUISE ENGINE FEED & TRANSFER SYSTEM

MAIN FEED DUCT (5"D)	156.4
FEED LINES (2, 3½"D) MAIN DUCT TO ENGINES	18.6
" " (2, 3¼"D) " " " "	4.7
" " (2, 2¾"D) " " " "	4.0
" " (2, 2"D) " " " "	2.2
" " (2, 1½"D) " " " "	1.3
INDIVIDUAL FEED LINES (10, 1½"D) TO ENGINES	3.2
ISOLATION VALVES TO ENGINES (D3/10X2.4#)	24.0
FEED LINES (2, 3½"D) FORWARD TANKS TO MAIN DUCT	21.5
FILL & XFER LINES (6, 3½"D) " " " " "	18.1
FEED LINES (6, 2"D) " " " " "	3.1
FEED & XFER PUMPS " " (Y1/6X15#)	90.0
FEED CHECK VALVES " " (R5/6X1.4#)	8.4
FILL & XFER SHUTOFF VALVES " " (G7/6X4.2#)	25.2
FILL & XFER ISOLATION VALVES " " (K7/6X3.8#)	22.8
FEED ISOLATION VALVES " " (K10/6X2.6#)	15.6
FEED LINES (2, 3½"D) AFT TANKS TO MAIN DUCT	22.8
FILL & XFER LINES (6, 3½"D) " " " " "	18.1
FEED LINES (6, 2"D) " " " " "	3.1
FEED & XFER PUMPS " " (Y1/6X15#)	90.0
FEED CHECK VALVES " " (R5/6X1.4#)	8.4
FILL & XFER SHUTOFF VALVES " " (G7/6X4.2#)	25.2
FILL & XFER ISOLATION VALVES " " (K9/6X3.8#)	22.8
FEED ISOLATION VALVES " " (K10/6X2.6#)	15.6
LINE FITTINGS (30% LINE WT.)	83.1
LINE SUPPORTS (18% LINE WT.)	49.9
FUEL PUMP INSTALLATION (13% PUMP WT.)	23.2
FUEL PUMP & VALVE CIRCUITRY (DC-8, 65, C-5B)	105.0
TOTAL	886.3

CRUISE ENGINE FEED SYSTEM

(#2)

$P = 150$ PSI (MAX OPERATING)

$P_{ULT} = 2.5 \times 150_{PSI} = 375$ PSI

$\sigma_{ULT} = 95{,}000$ PSI (ARMCO 21-6-9)

} MINIMUM GAGE - NOT PRESSURE DESIGNS ALL LINES.

LINE DIAMETER (IN)	MINIMUM GAGE (IN)
5	.020
$2\frac{1}{2} < D \leq 4$	.016
$1\frac{1}{2} < D \leq 2\frac{1}{2}$	.012
$D \leq 1\frac{1}{2}$	.010

MAIN DUCT TO ENGINES

(R3)

5" DIAMETER MAIN DUCT (ONE)

$t = \frac{PR}{\sigma} = \frac{375 \times 2\frac{1}{2}}{35{,}000} = .0099$ - MIN GAGE .020

$W_1 = \pi D L t \rho = \pi 5 (45 \times 12) .020 \times .286 = 156.4^{\#}$

3½" DIA (2 DUCTS) MAIN DUCT TO ENGINES

$t = .016$ MIN GAGE

$W_2 = 2 \times \pi D L t \rho = 2\pi (3\frac{1}{2})(15.4 \times 12) .016 \times .286 = 18.6^{\#}$

3¼" DIA (2 DUCTS)

$t = .016$ MIN GAGE

$W_2 = 2\pi D L t \rho = 2\pi (3\frac{1}{4})(4.17 \times 12) .016 \times .286 = 4.67^{\#} \sim 4.7$

2¾" DIA (2 DUCTS)

$t = .016$ MIN GAGE

$W_2 = 2\pi D L t \rho = 2\pi (2\frac{3}{4})(4.17 \times 12) .016 \times .286 = 3.95^{\#} \sim 4.0^{\#}$

2" DIA (2 DUCTS)

$t = .012$ MIN GAGE

$W_2 = 2\pi D L t \rho = 2\pi (2)(4.17 \times 12) .012 \times .286 = 2.23^{\#} \sim 2.2^{\#}$

1.5" DIA (2 DUCTS)

$t = .010$ MIN GAGE

$W_2 = 2 \times \pi D L t \rho = 2\pi (1.5)[4.17 \times 12] .010 \times .286 = 1.30^{\#}$

1.5" DIA INDIVIDUAL FEED LINES (10) TO ENGINES

$t = .010$ MIN GAGE

$W_{10} = 10 \times \pi D L t \rho = 10\pi 1.5 (24") .010 \times .286 = 3.14^{\#} \sim 3.2^{\#}$

(P4)

FORWARD FUEL TANKS (2) TO MAIN DUCT

3½" DIA LINES (2) FORWARD TANKS TO MAIN DUCT

$t_{MIN GAGE} = .016$

$W = 2\pi DLt\rho = 2\pi(3\tfrac{1}{2})(17'\times 12).016\times.286 = 21.5$

3½" DIA FILL & XFER LINES (6) TO FORWARD TANKS

$t_{MIN GAGE} = .016$

$W = 6\times\pi DLt\rho = 6\pi 3\tfrac{1}{2}(5'\times 12).016\times.286 = 18.1$

2" FEED LINES (6) FORWARD TANKS TO MAIN DUCT

$t_{MIN GAGE} = .012$

$W = 6\pi DLt\rho = 6\pi 2(2\times 12).012\times.286 = 3.1$

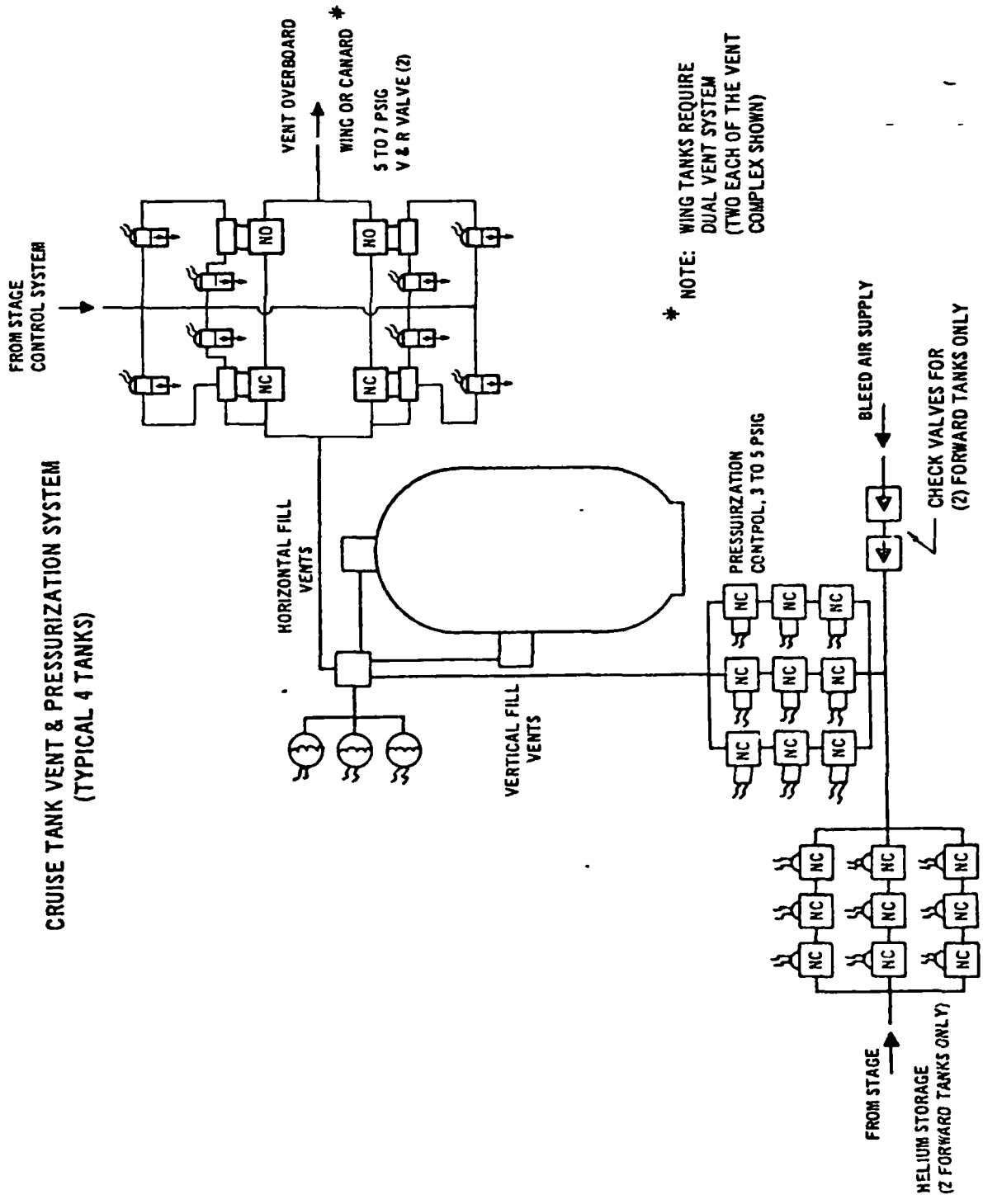
AFT (WING) TANKS (2) TO MAIN DUCT

3½" DIA LINES (2) FORWARD TANKS TO MAIN DUCT

$t_{MIN GAGE} = .016$

$W = 2\pi DLt\rho = 2\pi(3\tfrac{1}{2})(8'\times 12).016\times.286 = 22.8$

OTHER LINES SAME AS FOR FORWARD TANKS


CRUISE TANK VENT & PRESSURIZATION SYSTEM
(TYPICAL 4 TANKS)
FROM STAGE CONTROL SYSTEM
VENT OVERBOARD
WING OR CANARD *
5 TO 7 PSIG V & R VALVE (2)
NO
NC
HORIZONTAL FILL VENTS
VERTICAL FILL VENTS
PRESSURIZATION CONTPOL, 3 TO 5 PSIG
BLEED AIR SUPPLY
CHECK VALVES FOR (2) FORWARD TANKS ONLY
* NOTE: WING TANKS REQUIRE DUAL VENT SYSTEM (TWO EACH OF THE VENT COMPLEX SHOWN)
FROM STAGE
HELIUM STORAGE (2 FORWARD TANKS ONLY)

(85)

CRUISE PROPULSION
PRESSURIZATION & VENT SYSTEM

FWD TANKS – He Supply Isolation Valve (D6/2X3X1.2")	7.2
" " – He Supply shut-off Solenoid Valves (CS/2X1.2")	14.4
" " – He Supply lines (¼" line from tanks rear base)	.7
FWD & AFT TANKS – BLEED AIR CHECK VALVE (CT/4X2X.8")	6.4
" " " " – Press. Control Isolation Valve (D5/4X3X2.0")	24.0
" " " " – Press Control Isolation Valves (C4/4X6X1.8")	43.2
" " " " – 15' of ½" O.A. OVERBOARD VENT LINES	9.7
" " " " – 25' of 1" PRESS & VENT LINES	10.8
" – 3 PRESSURE REGULATORS UNESTIMATED (4X2")	8.0
" – VENT BOXES	24.8
" – VENT ISOLATION VALVES (K11/4X2X2.0")	16.0
" – VENT & RELIEF VALVES (L3/4X2X3.2")	25.6
" – CIRCUITRY (PLUS EST.)	20.0
" – LINE FITTINGS (30% OF LINES) 21.2"	6.4
" – LINE SUPPORTS (18% " ")	3.8
" – SUPPORTS (13% SYSTEM LESS LINES) (GD/A PROPOSAL)	24.6
TOTAL	245.6

(p6)

FWD TANKS He supply lines

TWO 1/4" LINES, t=.010, L=2000" each, STEEL

$W_4 = 2\times\pi DLt_f = 2\pi \times \frac{1}{4} \times 2000 \times .01 \times .286 = \frac{10}{4} \times .286 = .71^{\#}$

15' of 1½" DIA OVERBOARD VENT LINES (FOUR)
ONE PER TANK, 4 SETS

$W_4 = 4\times\pi DLt_f = 4\pi\ 1\tfrac{1}{2}(15\times12)\times.01\times.286 = 9.7^{\#}$

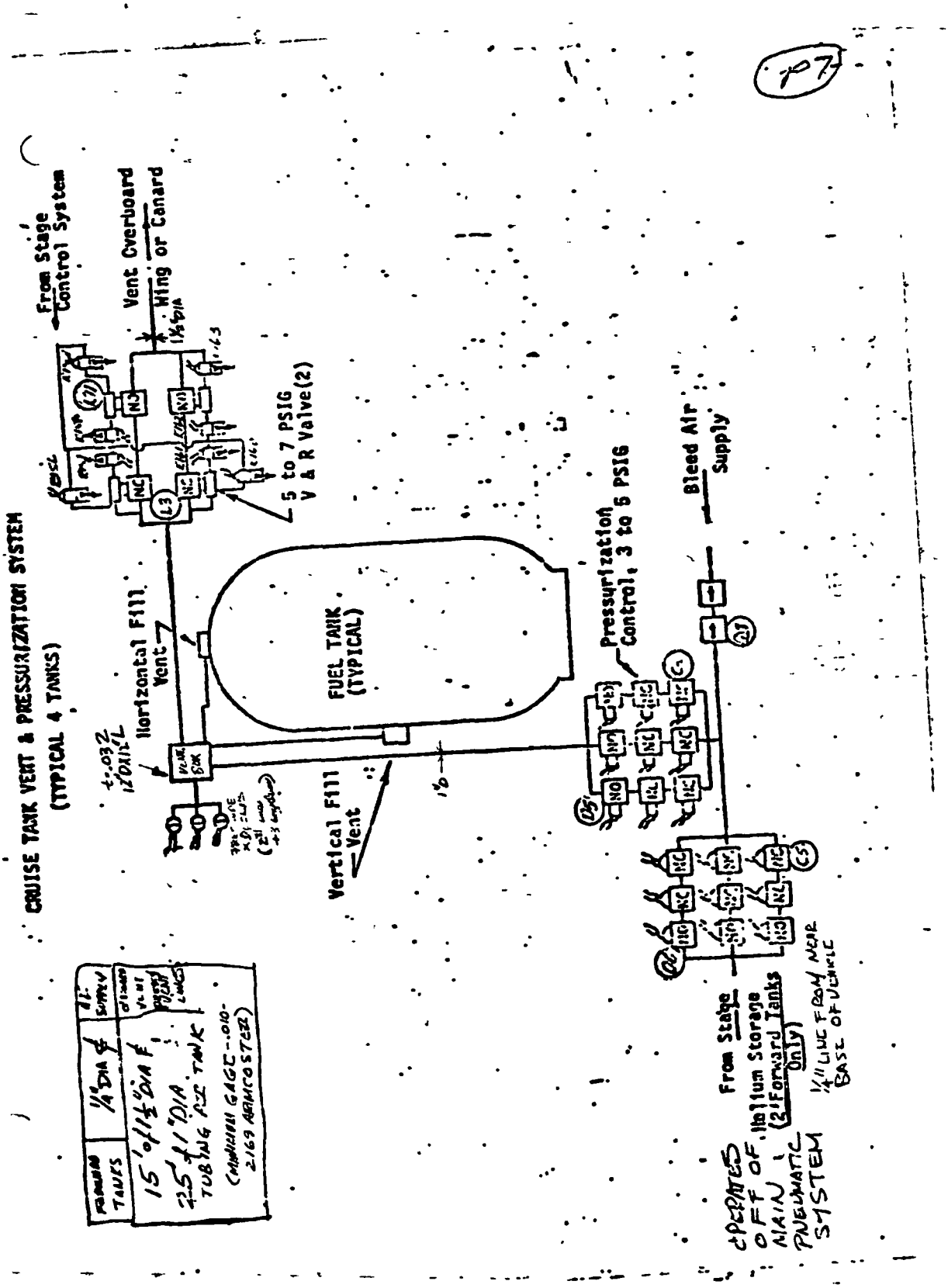
25' of 1" Dia Press & Vent Lines (Four)
one per tank

$W_4 = 4\times\pi DLt_f = 4\pi\ 1(25'\times12)\cdot01\times.286 = 10.8^{\#}$

VENT BOXES (12"DX12"long, t=.032) FOUR

$S = \pi R^2 + \pi DL = 2\pi(6)^2 + \pi\ 12\times12 = 226 + 452 = 678 in^2$

$W_4 = 4\ S t_f \rho = 4 \cdot 678 \times .032 \times .286 = 24.8^{\#}$


CRUISE TANK VENT & PRESSURIZATION SYSTEM
(TYPICAL 4 TANKS)
From Stage Control System
Vent Overboard
Wing or Canard
5 to 7 PSIG
V & R Valve(2)
Horizontal Fill
Vent
FUEL TANK
(TYPICAL)
Vertical Fill
Vent
Pressurization
Control, 3 to 5 PSIG
Bleed Air
Supply
From Stage
Helium Storage
(2 Forward Tanks
Only)
OPERATES
OFF OF
MAIN
PNEUMATIC
SYSTEM

(P8)

FILL, DRAIN & DUMP SYSTEM (CRUISE PROPULSION)

(NOTE: Some Fill components are included in the Feed & Xfer System)

MANUAL DRAIN VALVE & FITTING (V2/1 X 2.4#)	9.6#
FILL & DRAIN ISOLATION VALVE (KB/1 X 7.0#)	7.0
FILL & DRAIN VALVE (G9/1 X 7.4#)	7.4
FILL DISCONNECT (S5/1 X 3.0#)	3.0
OVERBOARD DUMP ISOLATION VALVE (K12/1 X 7.0#)	7.0
OVERBOARD DUMP VALVE (GB/1 X 7.4#)	7.4
LINES	43.1
LINE FITTINGS (30% OF LINES)	12.9
LINE SUPPORTS (18% OF LINES)	7.7
FUEL JETTISON CIRCUITRY & CONTROLS (C-133, 34#)	34.0
TOTAL	139.1#

LINES – 40' OF 5" DIA LINE, $t_{MIN} = .020$

$W = \pi D L t \rho = \pi 5 \times (40 \times 12) .020 \times .286 = 43.1\#$

(FOR VALVE ACTUATION)

PNEUMATIC SYSTEM (CRUISE PROPULSION)

(p9)

340' of 1/4" DIA tubing $P_{DT} = S.F \times P_{MAX} = 4 \times 1500 = 6000$ psi

$t = \frac{PR}{\sigma} = \frac{6000 \times .125}{95{,}000} = .0079 \sim .010 \pm .002$

tubing: $W = \pi D L t \rho = \pi \times .25 (340 \times 12) .010 \times .286 = \underline{9.2^{\#}}$

Valves. 86 @ 1#/each = $\underline{86^{\#}}$
(54 main system, 32 pressurization)

SUMMARY

pneumatic actuation control valves (86 @ 1# ea)	86.0
tubing (340' of 1/4" DIA)	9.2
Supports & installation (13% of Valves) (C-5A PROPOSAL)	11.2
Line fittings (30% of line wt)	3.1
line Supports (18% of line wt)	1.7#
TOTAL	111.2#

(P10)

BLEED AIR (CRUISE PROPULSION)

220' of 3/4" tubing, $P_{DT} = SF \times P_{MAX} = 4 \times 250 = 1000$ psi

$t = \frac{PR}{\sigma} = \frac{1000 \times .375}{95,000} = .004$ $t_{MIN} = .010$

$W_{TUBING} = \pi D L t \rho = \pi \times .75 (220 \times 12) \times .010 \times .286 = 17.8$#

SUMMARY (FOR CRUISE TANK PRESSURIZATION)

BLEED AIR ISOLATION VALVE (04/10X7.0#ea)	20.0#
TUBING	17.8
LINE FITTINGS (3/4" LINE OUT)	5.3
LINE SUPPORTS (1/2 LOAD WT)	3.2
TOTAL	46.3#

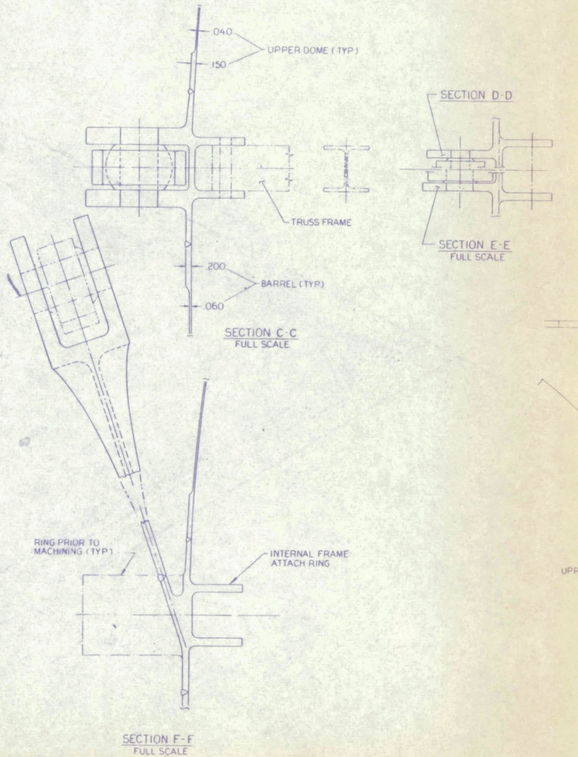
TANKAGE - CRUISE PROPULSION SYSTEM	2656
FWD TANKS (NON-INTEGRAL) - 2 REQ'D	1492
UPPER DOME (.040 ALUM)	252
SIDEWALL (.060 ALUM)	358
RING FRAME SPLICES & TIE RODS	182
FRAMES	196
LOWER DOME (.060 ALUM)	360
WELDS	5
BOLTS AND FITTINGS	41
UPPER TENSION LINKS (TITANIUM)	20
LOWER TENSION LINKS (TITANIUM)	30
UPPER RADIAL LINKS (ALUMINUM)	18
LOWER RADIAL LINKS (ALUMINUM)	18
FASTNERS & SPLICES	12
AFT TANKS (INTEGRAL/WING)	1164
SEAL FITTINGS & SEALANT	1164

FORWARD JP-4 TANKS

WEIGHT SUMMARY.
I.D = 115"
MAT. 2219-T87 Al ALLOY.

Vol = 860 FT^3 PER TANK

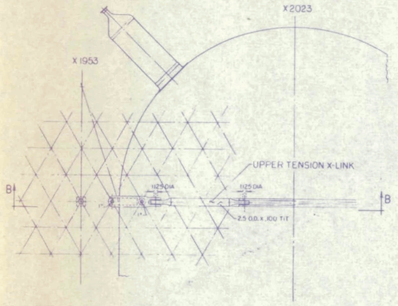
	WT LBS.
HEMISPHERE TOP DOME (.040 SKIN .150 LANDS) INCLUDES 24.5 DIAM COVER	= 125.8
HEMISPHERE BOTTOM DOME (.060 SKIN .200 LANDS) INCLUDES OUTLET COVER	= 180.1
AVERAGE = 55.7 IN BARREL SEC (.060 SKIN .200 LANDS)	= 181.4
RING FRAME SPLICES & TEE CAPS	= 91.0
FRAMES	= 98.0
BOLTS & FTGS	= 20.5
UPPER TENSION LINKS TITANIUM 2.5D (.100 WALL)	= 10.2
LOWER TENSION LINKS TITANIUM 2.5D (.100 WALL)	= 15.2
UPPER RADIAL LINKS Al 2.25 D (.040)	= 8.8
LOWER RADIAL LINKS Al 2.25 D (.040)	= 8.8
FASTENERS & SPLICES	= 6.0
TOTAL PER TK	745.8
TOTAL 2 TANKS	1492. LBS.



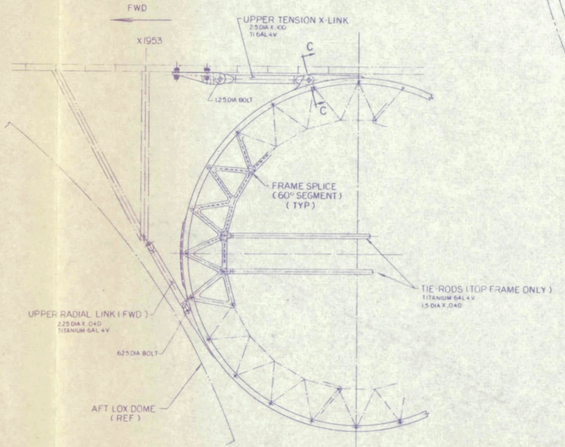
SECTION C-C
FULL SCALE

SECTION F-F
FULL SCALE

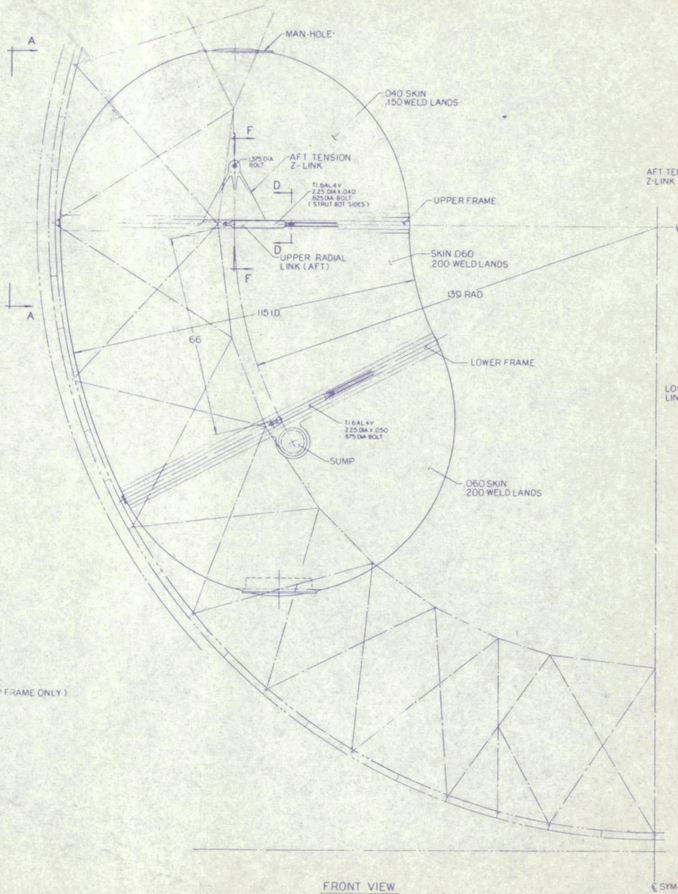
FULL SCALE



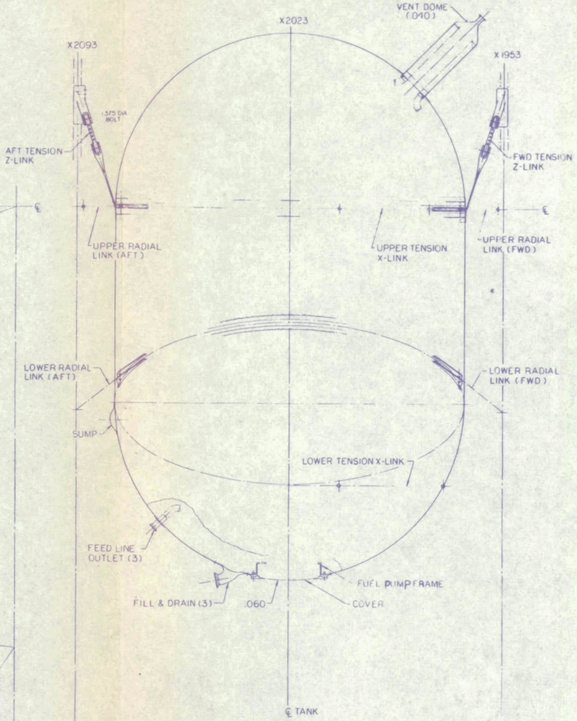
VIEW A-A
SCALE 1/10



SECTION B-B
SCALE 1/10



FRONT VIEW
LOOKING FWD
SCALE 1/10



SIDE VIEW
LOOKING OUTBOARD
SCALE 1/10

M.G. WINTER

JP-FUEL SYSTEM INSTALLATION
DETAILS JP-FUEL TANK

899A2020656

WING CRUISE TANKS

WING PLANFORM AREA $= \left(\frac{260+175}{2}\right)(320) = 69,600\ IN^2$
$484\ FT^2$

SEALANT — 1.2 LB PER FT^2 OF PLANFORM AREA

WEIGHT/TANK $= 1.2\ LB/FT^2 \times 484\ FT^2 = 582\ LB/TANK$

TOTAL WEIGHT = 1164 LB

CONTINGENCY

A TEN PERCENT CONTINGENCY WAS APPLIED TO ALL CRUISE PROPULSION COMPONENTS EXCEPT FOR THE BASIC ENGINES.

8. PROPULSION - AUXILIARY (ACPS)

5396

	FUEL	OXID.	TOTAL WEIGHT	PAGE NO.
THRUSTER INSTALLATION			[549]	
PROPELLANT SYS.	[1112]	[886]	[1998]	
FILL SYS.	(55)	(55)	(110)	2.8-7
VALVES	11	11		
PLUMBING	39	39		
SUPTS.	5	5		
PRESS. SYS.	(74)	(74)	(148)	2.8-9
VALVES	53	53		
PLUMBING	14	14		
SUPTS.	7	7		
VENT SYS.	(108)	(108)	(216)	2.8-11
VALVES	58	58		
PLUMBING	40	40		
SUPTS.	10	10		
FEED SYS.	(875)	(649)	(1524)	2.8-13
VALVES	187	235		
PLUMBING	608	355		
SUPTS	80	59		
TANKAGE	[1344]	[458]	[1802]	
STORAGE	(384)	(126)	(510)	2.8-18
TANK	253	73		
INTERNAL EQUIP.	48	16		
INSULATION	45	13		
SUPPORTS	30	16		
LEVEL INDICATORS	8	8		
ACCUMULATORS	(960)	(332)	(1292)	2.8-31
TANK	778	256		
INSULATION	-	-		
SUPPORTS	182	76		

8. PROPULSION - AUXILIARY (ACPS) - CONT'D

5396

	FUEL	OXID.	TOTAL WEIGHT	PAGE NO.
CONDITIONING EQUIP.	[450]	[359]	[809]	2.8-32
TURBO-PUMPS	86	139		
HEAT EXCHANGERS	219	148		
GAS GENERATORS	20	20		
SUPPORTS	35	32		
EXHAUST SYS.	70	-		
PLUMBING	20	20		
INSTRUMENTATION			[238]	2.8-34
MEASUREMENTS			186	
SUPPORTS			22	
WIRING			30	

8. PROPULSION – AUXILIARY		ATT. CONTROL		MANEU-VER	5396
THRUSTER INSTALLATION		549			
THRUSTER					
ACCESSORY					
PROPELLANT SY		1998			
FILL/DRAIN	110				
PRESSURIZATION	148				
VENT	216				
FEED SYSTEM	1524				
SUPPORTS	*				
TANKAGE		1802			
TANKS	510				
ACCUMULATORS	1292				
SUPPORTS	*				
CONDITIONING EQUIPMENT		809			
INSTRUMENTATION		238			

* WEIGHT INCLUDED IN EACH SUB-SECTION OF THE PROPELLANT SYS.

NOTE: A DETAILED DESCRIPTION OF THE ACPS CAN BE FOUND IN DOCUMENT SSPI-E450-57F

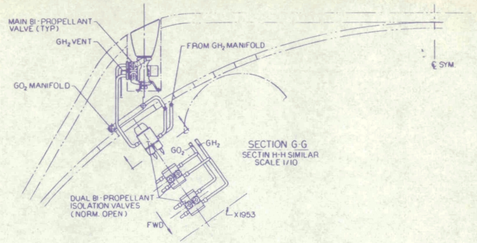
ACPS WEIGHT SUBSTANTIATION

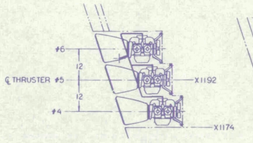
The booster Attitude Control Propulsion system (ACPS) provides attitude control and orientation for the booster mission operation. Nominal total impulse capability of the ACPS is 500,000 lb-sec. A reserve is provided for dispersions and malfunction conditions.

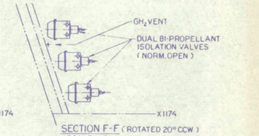
The system is made up of 16 thrusters located in the forward, mid-section, and aft section. Liquid hydrogen and oxygen are stored in low pressure vacuum tanks. The tanks have been sized to accomodate both the ACPS and APU requirements.

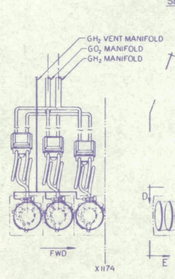
The propellants are conditioned by a turbopump-gas generator system. The conditioned propellants are stored in high pressure accumulators for use by the ACPS system.

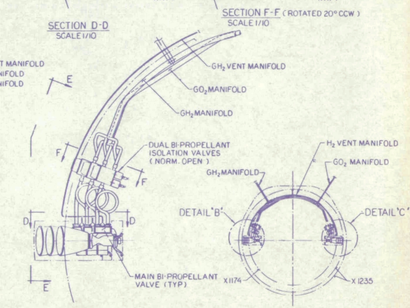
Line and component weights have been detailed to conform with the specific ACPS design.

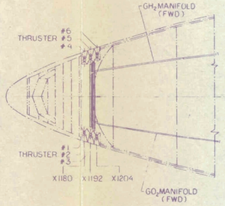


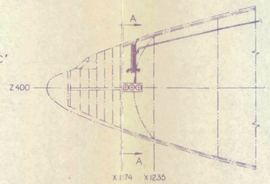


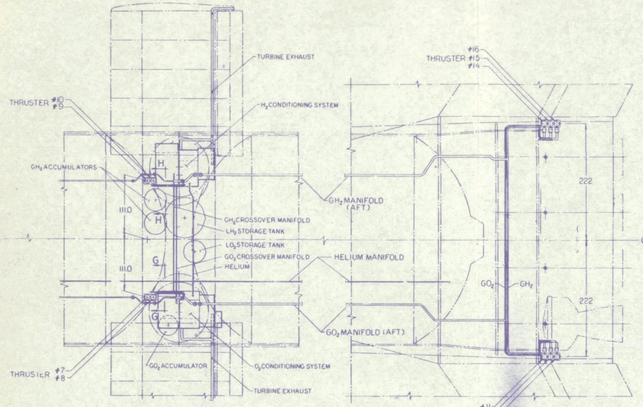


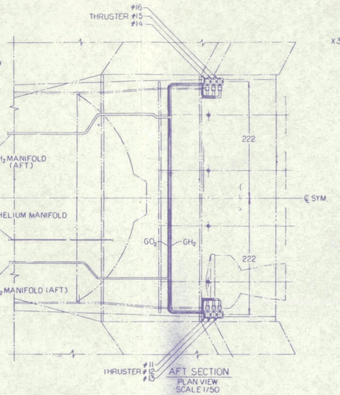


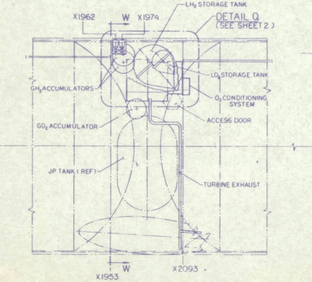


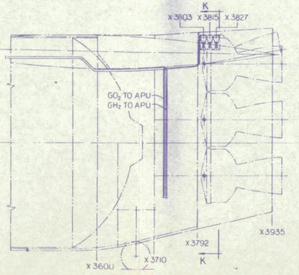


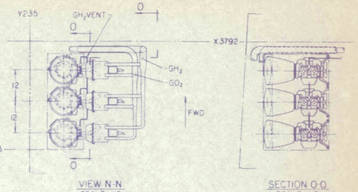


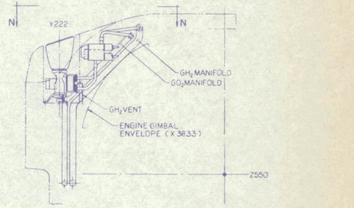


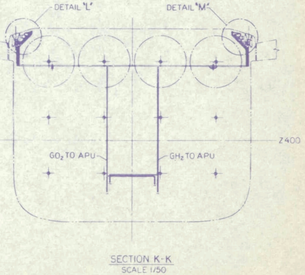


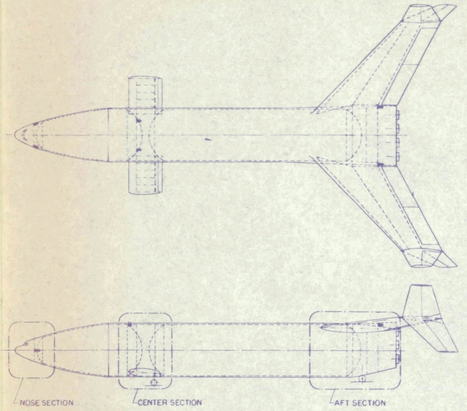


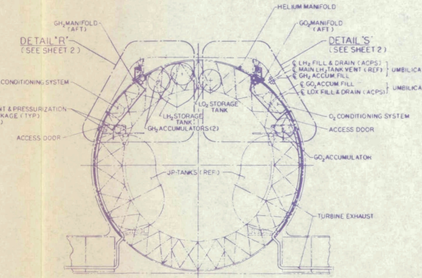




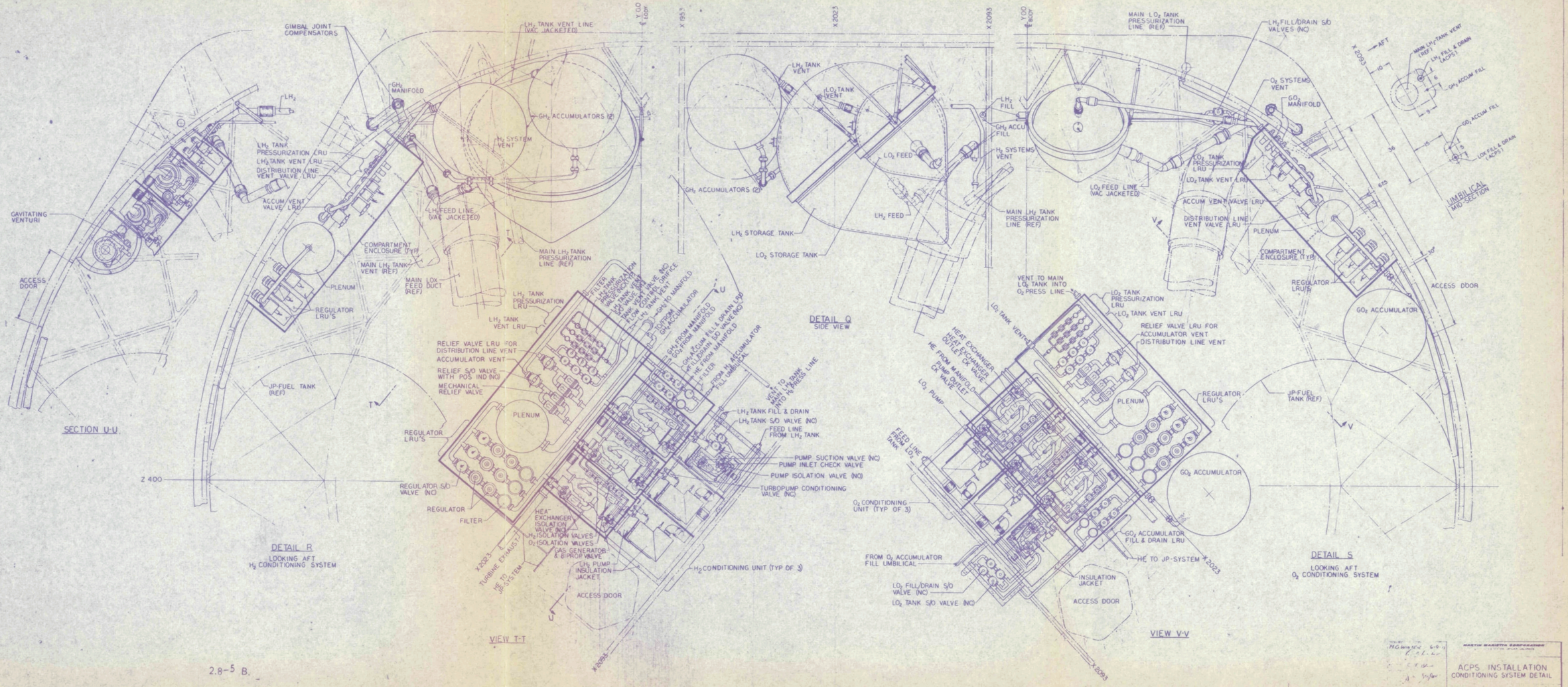








M.G. WINTER		MARTIN MARIETTA CORPORATION	
		ACPS INSTALLATION	
		899A2020 648	

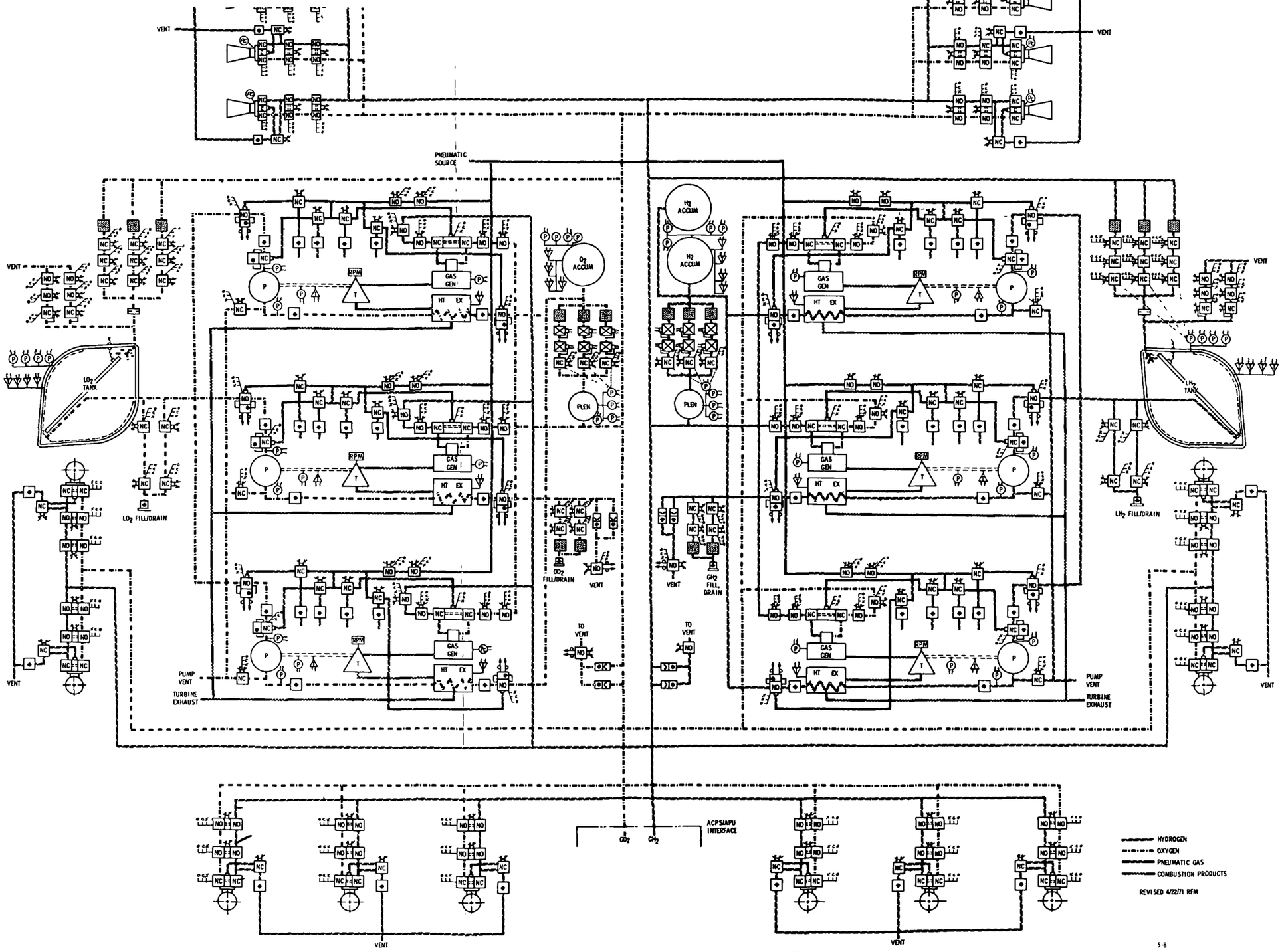


MARTIN MARIETTA CORPORATION

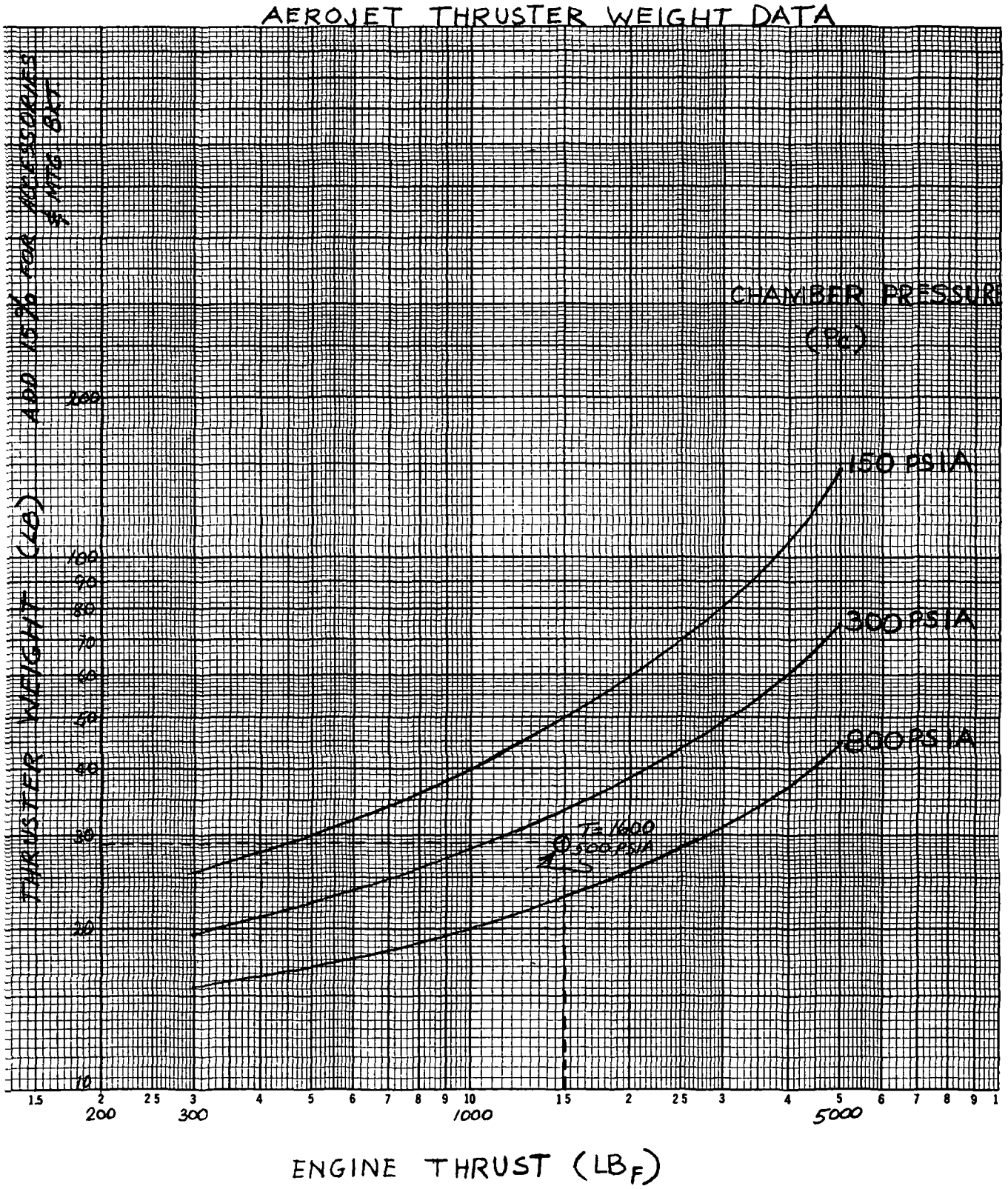
ACPS INSTALLATION
CONDITIONING SYSTEM DETAIL

899A2020648

SHEET 2 OF 3



2.8-5c **ACPS SYSTEM SCHEMATIC** (INSTRUMENTATION)


AEROJET THRUSTER WEIGHT DATA
ADD 15% FOR MISCELLANEOUS WEIGHTS
THRUSTER WEIGHT (LB)
CHAMBER PRESSURE (Pc)
150 PSIA
300 PSIA
600 PSIA
Tc 1600
500 PSIA
200
100
90
80
70
60
50
40
30
20
10
15
2
25
3
4
5
6
7
8
9
10
15
2
25
3
4
5
6
7
8
9
1
200
300
1000
5000
ENGINE THRUST (LBF)

DETAIL WEIGHT SUMMARY

	H_2	O_2	
FILL SYSTEM	[55]	[55]	110 LB
VALVES (SEE VALVE CHART)	(11)	(11)	
PLUMBING	(39)	(39)	
BASIC LINES	11	11	
FITTINGS 40%	5	5	
BELLOWS 3 REQ @ 4LB	12	12	
INSULATION	11	11	
SUPPORTS	(5)	(5)	
VALVE 10%	1	1	
LINE 10%	4	4	

ACPS FILL LINES

MATERIAL = STAINLESS STEEL (ARMCO 21 6 9)

OUTSIDE DIAM. INS.	WALL THICK. INS	LINE #/IN	LENGTH INS.	LINE WT	INS #/IN	INSUL. WT.
O_2 LN 2"	.016	.0283	400	11.3	.0273	10.9
H_2LN 2"	.016	0283	400	11.3	.0273	10.9
				22.6		21.8
			FTGS 40%	9.0		
				31.6		
			6 Bellows @ 4.0	24.0		
				55.6		
			SUPPORTS 10%	5.6		2.2
				61.2		24.0

TOTAL (85.2) lbs.

DETAIL WEIGHT SUMMARY

	H_2	O_2	
PRESSURE SYSTEM	[74]	[74]	148 LB
VALUES (SEE VALVE CHART)	(53)	(53)	
PLUMBING	(14)	(14)	
BASIC LINES	8	8	
FITTINGS 10%	3	3	
INSULATION	3	3	
SUPPORTS	(7)	(7)	
VALVES 10%	5	5	
LINE 10%	2	2	

ACPS PRESSURIZATION LINES

MATERIAL = STAINLESS STEEL (ARMCO 21-6-9)

	OUTSIDE DIAM INS.	WALL THICK INS	LINE #/IN.	LENGTH INS.	LINE WT	INSUL #/IN	INSUL WT
O_2	.375	.016	.0051	1500	7.7	.0020	3.0
H_2	.375	.016	.0051	1500	7.7	.0020	3.0
					15.4		6.0
		FITTINGS	40%		6.2		
					21.6		6.0
		SUPPORTS	10%		2.2		.6
					23.8		6.6
		TOTAL					(30.4) lbs.

DETAIL WEIGHT SUMMARY

	H_2	O_2	
VENT SYSTEM	[108]	[108]	216 LB
VALVES (SEE VALVE SECTION)	(58)	(58)	
PLUMBING	(40)	(40)	
BASIC LINES	17	17	
FITTINGS 40%	7	7	
INSULATION	16	16	
SUPPORTS	(10)	(10)	
VALVE 10%	6	6	
LINE 10%	4	4	

ACPS VENT LINES

MATERIAL = STAINLESS STEEL (ARMO 21-6-9)

	OUTSIDE DIAM INS	WALL THICK. INS	LINE #/IN	LENGTH INS	LINE WT.	INS #/IN	INSIDE DIA.
O_2	1.5"	.016	.0212	800	17.0	.020	16.0
H_2	1.5"	.016	.0212	800	17.0	.020	16.0
					34.0		32.0
WT FOR FITTINGS 40%					13.7		
					47.7		32.0
SUPPORTS 10%					4.8		3.2
					52.5		35.2

TOTAL (87.7) lbs.

DETAIL WEIGHT SUMMARY

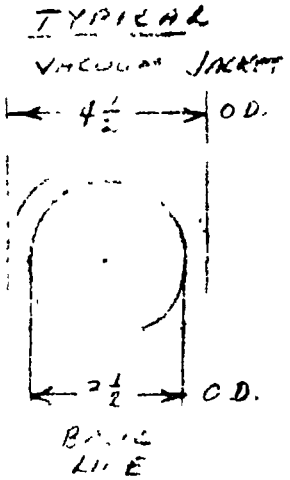
	H_2	O_2	
FEED SYSTEM	[875]	[649]	1524 LB
VALVES (SEE VALVE CHARTS)	(187)	(235)	
PLUMBING	(608)	(355)	
BASIC LINES	197	158	
VACUUM LINES	215	—	
FITTINGS 40% OF LINES	164	63	
BELLOWS			
H_2 / O_2			
3½" @ 7 LB / 3" @ 6 LB (4)	28	24	
2⅛" @ 4 LB / 1¾" @ 3 LB (1)	4	3	
SUPPORTS	(80)	(59)	
VALVES 10%	19	23	
LINE 10%	61	36	

RCPS FEED LINES

HYDROGEN FEED LINES

VACUUM JACKETED

DESIGN CONDITIONS FOR BASIC LINES



PRESSURE = 700 psi.

SAFETY FACTOR = 2 70° F (95,000 ARC, ULTIMATE)
except
1 1/4" LINE S.F = 4

MATERIAL = STAINLESS STEEL (ARMCO 21-6-9)

LINE	BASIC LINE O.D.	VACUUM JACKET O.D
ACCUMULATOR TO AFT.	3 1/2"	4 1/2"
AFT CROSSOVER	2 1/2"	3 1/2"
ACCUMULATOR TO FWD.	2 1/8"	3 1/8"
FWD CROSSOVER	2"	3"
MANIFOLD	2"	3"
INTER-TANK AREA	1 1/4"	2 1/4"

LINES CRITERIA — MINIMUM WALLS

DIAMETERS OVER 4" = .020 INS.

2 1/2 TO < 4 = .016 INS

1 1/2 TO < 2 1/2 = .012 INS

< 1 1/2 = .010 INS

ACPS

HYDROGEN FEED LINES

OUTSIDE DIAM. INS.	WALL THICK INS.	#/IN	LENGTH INS.	BASIC LINE WT LBS.	VI LBS
3 1/2	.026	.0811	1750	142.0	
4 1/2	.020	.0813	1750		142.3
2 1/2	.020	.0486	360	17.5	
3 1/2	.016	.0497	360		17.9
2 1/8	.016	0296	852	25.2	
3 1/8	.016	.0444	852		37.8
2	.016	.0283	168	4.7	
3	.016	.0426	168		7.2
2	.016	.0283	120	3.4	
3	.016	.0426	120		5.1
1 1/4	.020	.0219	180	4.0	
2 1/4	.012	.0243	180		4.5
			TOTALS	196.8	214.8

DEN 066037 (3-57)

ACPS FEED LINES

OXYGEN FEED LINES

MULTI-LAYER INSULATION .5 #/sq FT

DESIGN CONDITIONS FOR BASIC LINES

TYPICAL

PRESSURE = 700 psi

SAFETY FACTOR = 2 70°F (45 ksi/sq ULT)
except
$1\frac{1}{16}$" LINE SF = 4

MATERIAL = STAINLESS STEEL (ARMCO 26-6-9)

LINE	BASIC LINE O.D.
ACCUMULATOR TO AFT	3"
AFT CROSSOVER	2"
ACCUMULATOR TO FWD	$1\frac{3}{4}$"
FWD CROSS OVER	$1\frac{3}{4}$"
MANIFOLD	$1\frac{3}{4}$"
INTER-TANK AREA	$1\frac{1}{16}$"

DEN 066037 (3-57)

2.8-16

2.8 16

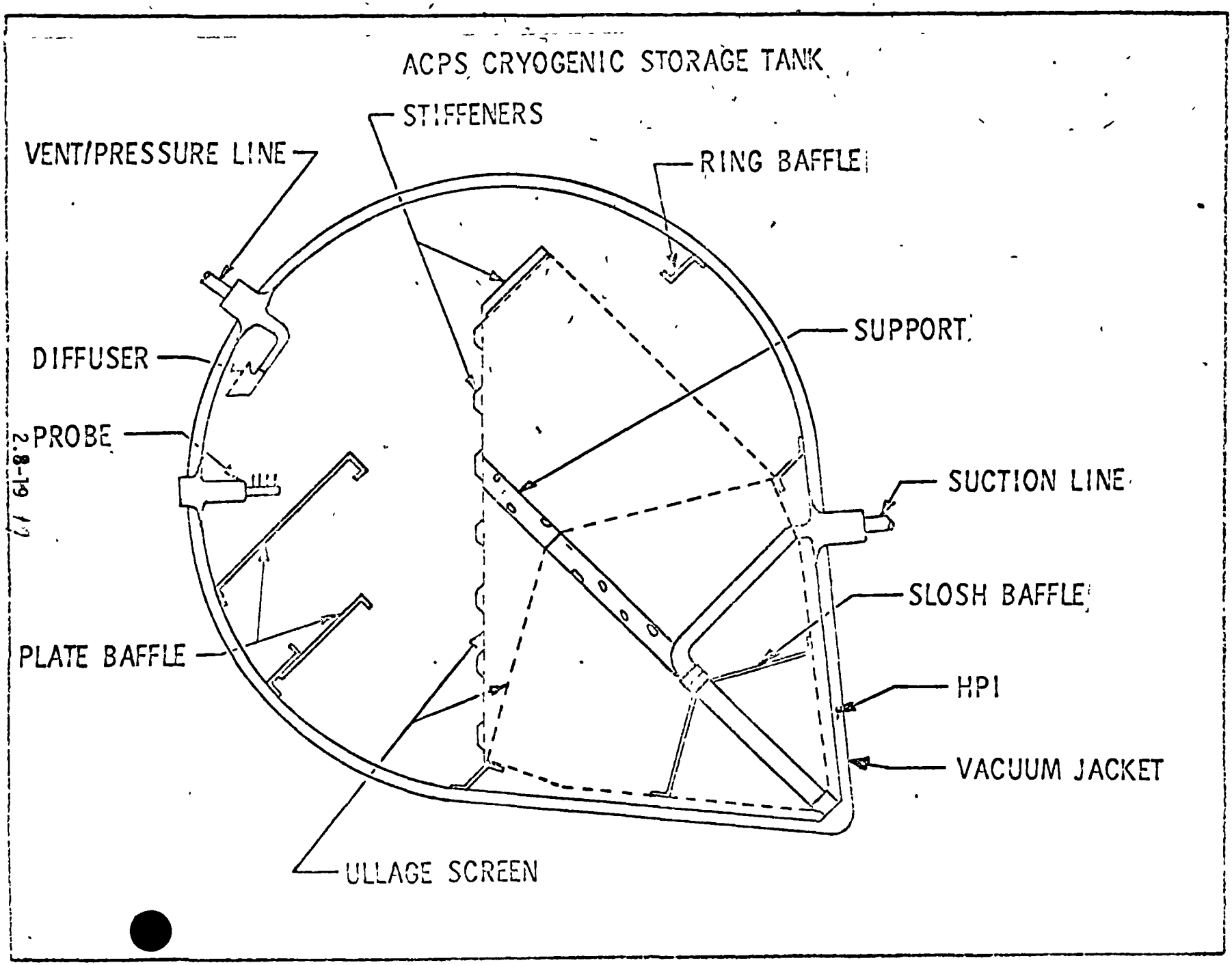
ACPS

OXYGEN FEED LINES.

OUTSIDE DIAM INS.	WALL THICK. INS.	LINE #/IN	LENGTH INS.	BASIC LINE WT LBS.	INSOLATION #/IN	INS. WT LBS.
3	.025	.0663	1750	116.1	.0380	66.4
2	.016	.0283	360	10.2	.0273	9.8
1 3/4	.016	.0246	851	21.0	.0246	21.0
1 3/4	.016	.0246	168	4.2	.0246	4.1
1 3/4	.016	.0246	120	3.0	.0246	3.0
1 1/16	.020	.0186	180	3.4	.0160	2.9
		TOTALS		157.9		107.2

ACPS HYDROGEN STORAGE TANK
WEIGHT SUMMARY

TANK (INNER MEMBRANE & JACKET)	=	253.4
INTERNAL EQUIPMENT	=	47.6
INSULATION	=	45.4
SUPPORTS	=	29.6
LEVEL SENSORS	=	8.3
TOTAL HYDROGEN STORAGE TANK	=	384.3#


ACPS CRYOGENIC STORAGE TANK
STIFFENERS
VENT/PRESSURE LINE
RING BAFFLE
SUPPORT
DIFFUSER
PROBE
SUCTION LINE
SLOSH BAFFLE
PLATE BAFFLE
HPI
VACUUM JACKET
ULLAGE SCREEN

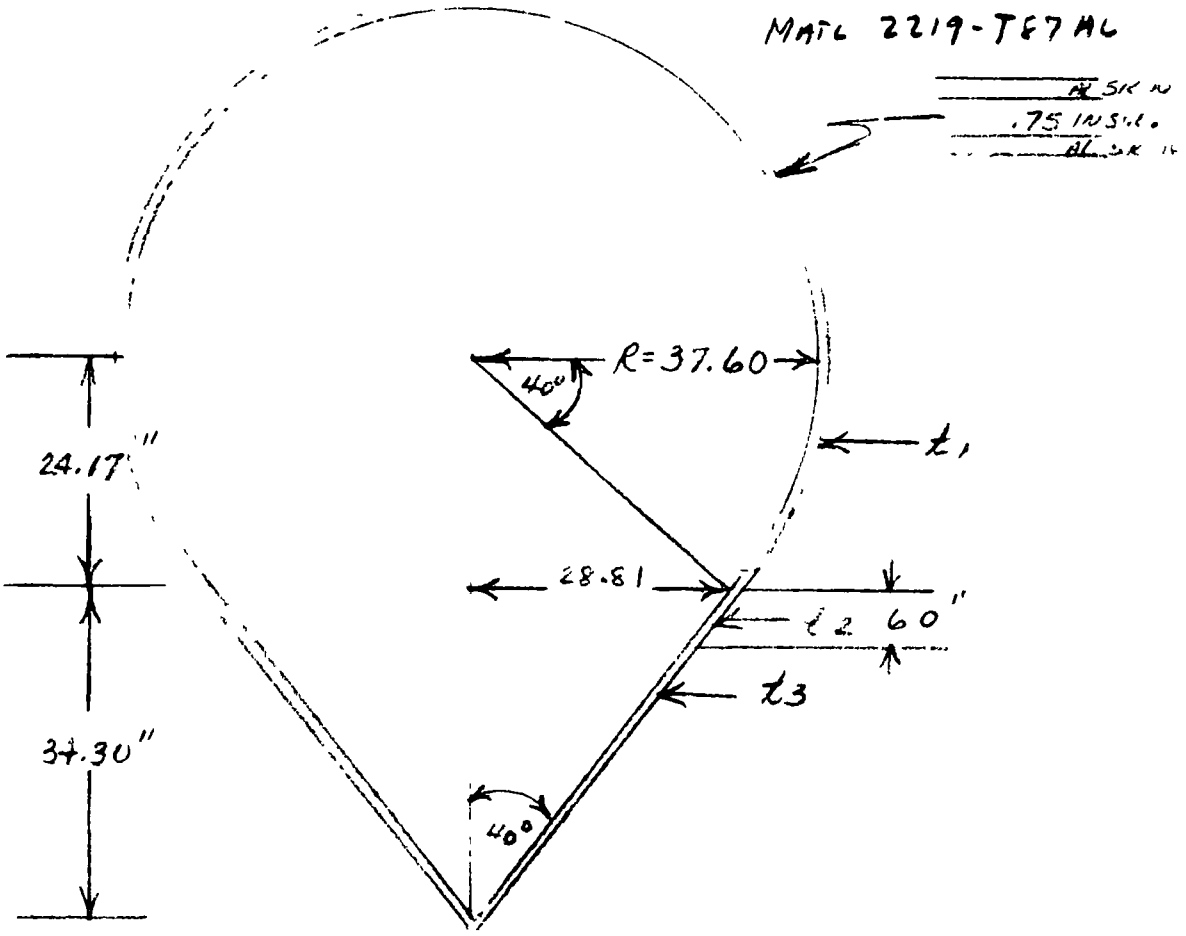
HYDROGEN STORAGE TANK

SAFETY FACTOR = 2 (ULTIMATE) $F_{TU} = 62{,}000$

DOUBLE WALL VACUUM INSULATED JACKET

VOLUME = 135 FT^3 MAX TANK P = 35 psi

MAT'L 2219-T87 AL



SEMI-HEMISPHERE & SPHERICAL SEGMENT

MINIMUM THICKNESS

$$t_1 = \frac{.5(35)(37.60)(2)}{62{,}000} = .0212 \text{ use } .040$$

$$t_2 = \frac{1.3(28.83)(35)(2)}{62{,}000} = .042 + .005 = .047$$

$$t_3 = \frac{1.3(23.85)(35)(2)}{62{,}000} = .035 + .005 = .040$$

ACPS HYDROGEN STORAGE TANK

AREAS:

INNER ALUMINUM MEMBRANE

SEMI-HEMISPHERE = $2\pi R^2 = 2\pi(37.62)^2 =$ 8892.39 in^2

SPHERICAL-SEGMENT = $2\pi R^2 - 2\pi R(R-24.17) =$ 5713.16 in^2

CONE = $\pi(28.83)\sqrt{(28.83)^2+(34.32)^2}$ = 4059.65 in^2

TOTAL 18,665.2 in^2

OUTER VACUUM ALUMINUM JACKET

SEMI-HEMISPHERE = $2\pi R^2 = 2\pi(38.43)^2 =$ 9279.44 in^2

SPHERICAL-SEGMENT = $2\pi R^2 - 2\pi R(R-24.17) =$ 5836.17 in^2

CONE = $\pi(29.66)\sqrt{(29.66)^2+(35.15)^2}$ = 4285.50 in^2

TOTAL 19,401.1 in^2

INSULATION (LBI. INSULATION TYPE - Beech Aircraft) .3437 #/ft

SEMI-HEMISPHERE = $2\pi R^2 = 2\pi(38.62)^2 =$ 9082.50 in^2

SPHERICAL-SEGMENT = $2\pi R^2 - 2\pi R(R-24.17) =$ 5773.91 in^2

CONE = $\pi(29.23)\sqrt{(29.23)^2+(34.72)^2}$ = 4167.72 in^2

19,024.13 in^2

or

132.1 sq. ft.

ACPS HYDROGEN STORAGE TANK

WEIGHTS:

INNER MEMBRANE - SEMI-hemisphere & Spherical Segment

$14,605.55\ in^2 (.040)(.102) =$ 59.6 #

INNER MEMBRANE - CONE

$3043.2\ in^2 (.040)(.102) =$ 12.4 #

$1016.4\ in^2 (.044)(.102) =$ 4.6

76.6

WELD MATERIAL $(256 \times .002\ \#/in) =$ 0.5

TOTAL INNER MEMBRANE WEIGHT = 77.1 #

INSULATION WEIGHT

$132.1\ sq\ ft\ (.3437\ \#/sq\ ft) =$ 45.4 #

OUTER VACUUM JACKET - Semi-hemisphere & spherical segment

$15,115.61 (.080)(.102) =$ 123.3

CONICAL SECTION $4,285.50 (.120)(.102) =$ 52.5

WELD MATERIAL $(242 \times .002) =$ 0.5

TOTAL OUTER VACUUM JACKET = 176.3 #

ACPS HYDROGEN STORAGE TANK

WEIGHTS CONT.

INTERNAL EQUIPMENT

BAFFLES.

SLOSH BAFFLE

$18\pi(.04)(19.2)(.102)$ = 4.4

RING BAFFLE

$75.2\pi(.04)(6.0)(.102)$ = 5.7

PLATE BAFFLES

$\frac{1}{2}\pi(16)^2(.04)(.102)$ = 1.6

$\frac{1}{2}\pi(11)^2(.04)(.102)$ = 0.8

ATTACHMENTS & FASTENERS 15% = 1.8

Mesh screen liner:

60% (130 SQ FT)(.33 #/FT²) = 25.7

INTERNAL SUPPORT TUBE: 3" O.D.

62 IN. (.039 #/IN) = 2.4

INTERNAL SUCTION LINE 2" O.D

65(.0258 #/IN) = 1.7

METALLIC COUPLING

12(.124 #/IN) = 1.5

DIFFUSER (EST.) = 2.0

TOTAL INTERNAL EQUIP = 47.6 LBS.

DEN 066037 (3-57)

ICPS HYDROGEN STORAGE TANK

WEIGHTS - CONT.

SUPPORTS

TANK LUGS (3)

$3(\pi)(1)^2(2)(.102)$ = 1.9 lbs

SUPPORT TUBES (3)

3" OD (.109 wall) AL

$3(.099\ \#/in)(80\ in)$ = 23.8

ATTACHMENTS & FASTENERS = 3.9

15%

TOTAL 29.6

Level Sensors

Level Sensors 6 @ .125	= .8
AMPLIFIER	= 1.3
SUPT	= .2
WIRING	= 4.5
CONNECTORS & SUPT	= 1.5
TOTAL.	8.3 lbs

ACPS OXYGEN STORAGE TANK
WEIGHT SUMMARY

TANK (INNER MEMBRANE & JACKET) =	72.7
INTERNAL EQUIPMENT	16.1
INSULATION	12.9
SUPPORTS	16.3
Level Sensors	8.3
TOTAL OXYGEN STORAGE TANK =	126.3

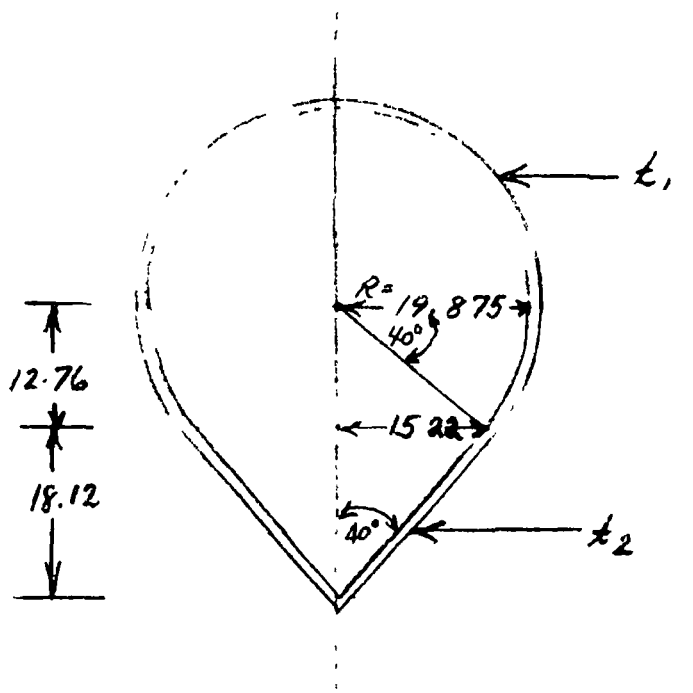
ACPS OXYGEN STORAGE TANK

MATERIAL 2219-T87 AL

SAFETY FACTOR = 2 (ULTIMATE) F_{tu} = 62000 psi

DOUBLE WALL VACUUM INSULATED JACKETS

VOLUME = 20 FT^3 MAX TANK P = 35 psi



semi- Hemisphere & spherical segment

MINIMUM THICKNESS

$$t_1 = \frac{.5(35)(19.875)(2)}{62,000} = .011 \text{ use } .040 \text{ MIN GAUGE}$$

$$t_2 = \frac{1.3\,(15.22)(35)(2)}{62.000} = .022 \text{ use } .040 \text{ MIN GAUGE}$$

RCS OXYGEN STORAGE TANK

AREAS:

INNER ALUMINUM MEMBRANE

SEMI-HEMISPHERE $= 2\pi(R)^2 = 2\pi(19.895)^2 =$ 2486.96 in^2

SPHERICAL SEGMENT $= 2\pi(R)^2 - 2\pi R(R - 12.76) =$ 1595.06 in^2

CONE $= \pi(15.24)\sqrt{(15.24)^2 + (18.14)^2} =$ 1134.33 in^2

TOTAL 5216.35 in^2

OUTER VACUUM ALUMINUM JACKET

SEMI-HEMISPHERE $= 2\pi(R)^2 = 2\pi(20.705)^2 =$ 2693.59 in^2

SPHERICAL SEGMENT $= 2\pi(R)^2 - 2\pi R(R - 12.76) =$ 1660.00 in^2

CONE $= \pi(16.07)\sqrt{(16.07)^2 + (18.97)^2} =$ 1255.15 in^2

TOTAL 5608.74 in^2

INSULATION (LB.I INSULATION TYPE Beech AIRCRAFT)

SEMI-HEMISPHERE $= 2\pi(R)^2 = 2\pi(20.29)^2 =$ 2586.69 in^2

SPHERICAL SEGMENT $= 2\pi R^2 - 2\pi R(R - 12.76) =$ 1626.72 in^2

CONE $= \pi(15.64)\sqrt{(15.64)^2 + (18.54)^2} =$ 1191.79 in^2

TOTAL 5405.20 in^2

OR

37.529 ft^2.

RCPS OXYGEN STORAGE TANK

WEIGHTS:

INNER MEMBRANE, BRINE TANK

5211.35 (.040)(.102) = 21.2 lbs

WELD MATERIAL
(125 x .002 #/IN) = 0.3

TOTAL INNER MEMBRANE WEIGHT = 21.5 lbs

INSULATION WEIGHT

37.5 sq ft (.3437 #/sq ft) = 12.9 lbs

OUTER VACUUM JACKET

SEMI-HEMISPHERE & SPHERICAL SEGMENT

4353.54 in^2 (.080)(.102) = 35.5

CONICAL SECTION

1255.15 (.120)(.102) = 15.4

WELD MATERIAL
(130 x .002 #/IN) = 0.3

TOTAL OUTER VACUUM JACKET = 51.2 lbs

HSP OXYGEN STORAGE TANK

WEIGHTS. CONT.

INTERNAL EQUIPMENT

BAFFLE.

SLOSH BAFFLE
$14\pi(.04 \times 2)(\ldots)$ = .2

RING BAFFLE
$35\pi(.04)(4.0)(.102)$ = 1.9

PLATE BAFFLES
$\frac{1}{2}\pi(10)^2(.04)(.102)$ = 0.6

$\frac{1}{4}\pi(6)^2(.04)(.102)$ = 0.2

[illegible] FASTENER
15 [illegible] = 0.7

[illegible]
[illegible] (3[illegible] sq FT)(.3[illegible] FT²) = 7.[illegible]

[illegible] SUPPORT [illegible]
32(.026 #/IN) = 0.8

[illegible] COUPLING
12([illegible] #/IN) = [illegible]

DIFFUSE (FST) 1.[illegible]

TOTAL INTERNAL EQUIP 16.1 [illegible]

DEN 066037 (3-57)

ACPS OXYGEN STORAGE TANK

WEIGHTS CONT.

SUPPORTS.

TANK LUGS (3)

$3\pi(.5)^2(2)(.102)$ = 0.5

SUPPORT TUBES (3)

2" O.D (.109 WALL)

3 (.065 #/IN)(70 IN) = 13.7

ATTACHMENTS & FASTENERS = 2.1

15%

TOTAL 16.3

Level Sensors

Level Sensors 6 @ .125	= .8
AMPLIFIER	= 1.3
SUPT	= .2
WIRING	= 4.5
CONNECTORS & SUPT	= 1.5
TOTAL	8 3 lbs

ACPS HYDROGEN ACCUMULATOR

2 REQUIRED

WEIGHT SUMMARY

	WEIGHT
* TANKS 2 @ 389 EA	778
INSULATION	NONE REQ'D
SUPPORTS	182
TOTAL	960 LBS.

ACPS OXYGEN ACCUMULATOR

1 REQUIRED

WEIGHT SUMMARY

* TANK	256
INSULATION	NONE REQ'D
SUPPORTS	76
	332 LBS.

* FOR COMMONALITY PURPOSES - TANK WEIGHTS ARE THE SAME AS THE ORBITER TANK WEIGHTS (RECEIVED FROM MDAC-ED)

ACPS-CONDITIONING EQUIPMENT

	HYDROGEN SYS. LBS.	OXYGEN SYS. LBS.
TURBO-PUMPS		
3 @ 28.53	85.6	
3 @ 46.2		138.6
HEAT EXCHANGERS		
3 @ 73.07	219.2	
3 @ 49.27		147.8
GAS GENERATORS		
3 @ 6.66	20.0	
3 @ 6.66		20.0

FOR COMMONALTY PURPOSES THE ABOVE ITEMS AND WEIGHTS ARE THE SAME AS THE CONDITIONING EQUIPMENT ITEMS USED ON THE ORBITER. (Received from MDAC-ED)

PLUMBING		
STEEL TUBING		
3/4" Rev. 300" (.016) =	3.2	3.2
1" " 300" (.016) =	4.2	4.2
1 1/2" " 300" (.016) =	6.4	6.4
	13.8	13.8
FITTINGS 40%	5.5	5.5
	19.3	19.3
SUPPORTS		
10% OF EQUIP & LINES	35.0	32.0

ACPS - CONDITIONING EQUIPMENT

ACPS EXHAUST LINE

MATERIAL STAINLESS STEEL ARMCO (21-6-9)

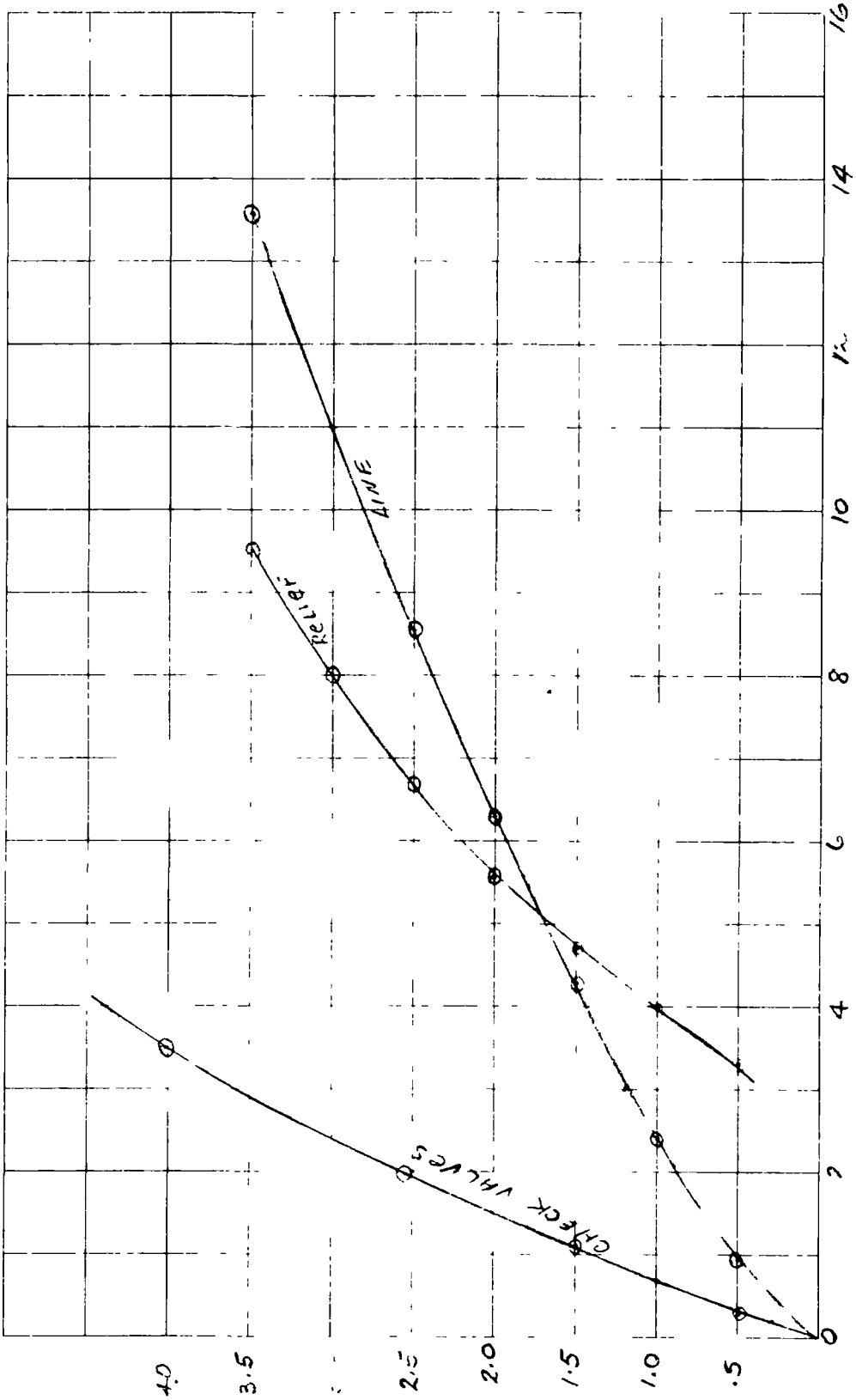
OUTSIDE DIAMETER = 4"
WALL THICKNESS = .016"
WEIGHT/INCH = .056 LBS/INS
LENGTH = 800"

LINE WEIGHT = 45 lbs
FITTINGS - 40% - 18 lbs
SUPPORTS - 10% = 7 lbs

TOTAL - 70 lbs

ACPS INSTRUMENTATION

	WT-LBS
207 PRESSURE TRANSDUCERS @ 0.375	77.6
127 TEMPERTURE TRANSDUCERS @ 0.2	25 +
828 VALVE & COMPONENT TRANSDUCERS @ 0.1	82.8
WIRING 22 GAUGE (10,000 FT)	30.0
SUPPORTS 10 %	21.6
TOTAL WT =	237.4


RELIEF LINE
CHECK VALVES
16
14
12
10
8
6
4
2
0
4.0
3.5
2.5
2.0
1.5
1.0
.5

VAN WEIGHT

		H_2	O_2
1	FILL SYS	0	[illegible]
2	FEED SYS	187.0	[illegible]
4	[illegible]	[illegible]	[illegible]
5	VENT SYS	[illegible]	[illegible]
	TOTALS	301.4	[illegible]

ACPS VALVES & COMPONENTS CKT - SYS.

	ITEM	QTY	UNIT	TOTAL WT.	F	D	P	V
1	LO_2 FILL QUICK DISCONNECT	1	1.0	1.0	F			
2	LO_2 FILL & DRAIN SHUT-OFF	4	2.5	10.0			P	
3	O_2 GAS DIFFUSER	1	1.0	1.0				V
4	O_2 TANK VENT SHUT OFF	2	4.0	8.0				V
5	O_2 TANK VENT	4	2.5	10.0			P	
6	FLOW CONTROL ORIFICE	1	0.5	0.5			P	
7	O_2 TANK PRESSURE	9	0.8	7.2		D		
8	LO_2 PUMP ISOLATION	3	4.3	12.9		D		
8A	LO_2 PUMP INLET SUCTION	3	4.3	12.9		D		
9	LO_2 PUMP CHECK	3	1.2	3.6			P	
10	HELIUM FILL	12	1.4	16.8			P	
11	HELIUM CHECK	12	0.3	3.6			P	
12	HELIUM ISOLATION	6	1.0	6.0		D		
13	GOX GEN PRESSURE BI-PASS	3	1.1	3.3		D		
14	GOX GEN ISOLATION	12	1.3	15.6		D		
15	PUMP OUTLET CHECK	3	1.2	3.6		D		
16	HX EXCHANGER - CHECK	3	1.4	4.2		D		
17	HX EXCHANGER ISOLATION	3	5.4	16.2		D		
18	TURB PUMP VENT	3	2.4	7.2				V
19	[illegible]	3	5.0	15.0		D		
20	REGULATOR	6	6.16	[illegible]		D		
21	[illegible]	3	5.2	15.6		D		
[illegible]	[illegible]	1	14.2	14.2		D		
24	THRUSTER ISOLATION	32	2.0	70.4		D		
25	GO_2 FILL & DRAIN SHUT-OFF	4	2.5	10.0			P	
26	CO_2 GAS FILTER	2	3.5	7.0			P	
27	GOX QUICK DISCONNECT	1	1.0	1.0			P	
28	GO_2 [illegible] RELIEF	4	5.3	21.2				V
29	GO_2 RELIEF SHUT OFF	2	5.7	11.4				V
			TOTAL	(357.2)	(11.0)	(235.3)	(53.1)	(57.8)

ACPS VALVES & COMPONENTS - HYDROGEN SYS

NO	ITEM	QTY	UNIT WT	TOTAL WT	CODE SYS F	D	P	V
41	LH_2 FILL QUICK DISCONNECT	1	1.0	1.0	F			
42	LH_2 TANK FILL & DRAIN SHUT-OFF	4	2.5	10.0	F			
43	H_2 GAS DIFFUSER	1	1.0	1.0			P	
44	H_2 VENT SHUT-OFF	2	4.0	8.0				V
45	H_2 TANK VENT	4	2.5	10.0				V
46	FLOW CONTROL ORIFICE	1	0.5	0.5			P	
47	H_2 TANK PRESSURE	9	0.8	7.2			P	
48	LH_2 PUMP ISOLATION	3	4.3	12.9		D		
48B	LH_2 PUMP INLET SUCTION	3	4.3	12.9		D		
49	LH_2 PUMP CHECK	3	1.2	3.6		D		
50	HELIUM PILOT	12	1.4	16.8			P	
51	HELIUM CHECK	12	0.3	3.6			P	
52	HELIUM ISOLATION	6	1.0	6.0			P	
53	GAS GEN. PNEUMATIC BI-PROP	3	1.3	3.9		D		
54	GAS GEN. ISOLATION	12	1.3	15.6		D		
55	PUMP OUTLET CHECK	3	1.2	3.6		D		
56	HEAT EXCHANGER - CHECK	3	1.4	4.2		D		
57	HEAT EXCHANGER ISOLATION	3	5.4	16.2		D		
58	TURBO PUMP VENT	3	2.4	7.2				V
59	FILTER	3	5.0	15.0		D		
60	REGULATOR	6	6.8	40.8		D		
61	REGULATOR - SHUT OFF	3	5.2	15.6		D		
62	PLENUM CHAMBER	1	36.3	36.3		D		
63	GH_2 CHECK	16	0.4	6.4		D		
65	GH_2 FILL & DRAIN SHUT-OFF	4	2.5	10.0			P	
66	GH_2 GAS FILTER	2	3.5	7.0			P	
67	GH_2 QUICK DISCONNECT	1	1.0	1.0			P	
68	GH_2 MECH. VENT RELIEF	4	5.3	21.2				V
69	GH_2 RELIEF SHUT OFF	2	5.7	11.4				V
			TOTAL	(308.4)	(110)	(187.0)	(53.1)	(57.3)

HYDROGEN RESERVE & OXYGEN RESERVE DERIVATIONS

ACPS

H_2 - [USABLE] 221 × 5% = 11 lbs

O_2 = [USABLE] 991 × 5% = 50 lbs

APU

H_2 = [USABLE] 168 × 10% = 17 lbs

O_2 = [USABLE] 126 × 10% = 13 lbs

ROOT SUM SQUARED

$H_2 = \sqrt{11^2+17^2} = \sqrt{410} = 20.2$

$O_2 = \sqrt{50^2+13^2} = \sqrt{2669} = 51.6$

ACPS

RESERVE PROP. HYDROGEN = $\frac{11^2}{11^2+17^2} \times 20.2 = \underline{6}$ lbs

OXYGEN = $\frac{50^2}{50^2+13^2} \times 51.6 = \underline{48}$ lbs

APU

RESERVE PROP

HYDROGEN = $\frac{17^2}{11^2+17^2} \times 20.2 = \underline{14}$ lbs

OXYGEN = $\frac{13^2}{50^2+13^2} \times 51.6 = \underline{3}$ lbs

NOTE: WEIGHT CARRIED IN RESERVE FLUIDS SECT. 2.25

BOOSTER BASELINE ACPS/APU PROPELLANT REQUIREMENTS

PROPELLANT INVENTORY	ACPS	APU	SERVICE	TOTAL
HYDROGEN USABLES	221	168	139	528
HYDROGEN RESERVES	6	14	-	20
HYDROGEN PUMP COOLING	5	-	-	5
HYDROGEN RESIDUALS (2%)	5	4	3	12
* H_2 ACCUMULATOR/LINE RESIDUALS	* (46)	-	-	(46)
TOTAL HYDROGEN LOADED *IN TANK.*	237	186	142	565
OXYGEN USABLES	991	126	139	1256
OXYGEN RESERVES	48	3	-	51
OXYGEN PUMP COOLING	4	-	-	4
OXYGEN RESIDUALS (2%)	21	3	3	27
* O_2 ACCUMULATOR/LINE RESIDUALS	* (213)	-	-	(213)
TOTAL OXYGEN LOADED *IN TANK.*	1064	132	142	1338

* NOT INCLUDED IN TANK SIZING

H_2 LOADED IN TANK + LINES 611 lbs

O_2 LOADED IN TANK + LINES 1551 lbs

9. PRIME POWER

3582

	WEIGHT (LB)	PAGE NO.
TANKAGE - STORAGE (COMMON TANKS - CODED TO ACPS)		
TURBO-POWER SYS.	[302]	2.9-7
TURBINES	(176)	
GAS GENERATORS	(22)	
CONTROL LOGIC & INSTRUMENTATION	(68)	
CONTROL VALVES	(36)	
HEAT EXCHANGERS	[173]	2.9-7
RECUPERATORS	(133)	
GEAR BOX COOLERS	(18)	
EQUALIZERS	(22)	
ALTERNATORS	[184]	
DISTRIBUTION SYS.	[295]	2.9-9
LINES & FITTINGS	(32)	
TURBINE EXHAUST LINES	(238)	
VALVES	(12)	
MANIFOLD LINES	(13)	
GEAR BOX ASSY.	[451]	2.9-7
GEAR BOXES	(390)	
LUBE OIL	(61)	
HYDRAULIC PUMPS (CODED TO HYDRAULICS)	-	
AIR BREATHERS - APU	[1816]	2.9-10
POWER UNITS (JP/AIR)	(1156)	
CLUTCHES	(70)	
INLET & EXHAUST DUCTS	(590)	
BATTERY	[35]	2.9-13
SUPPORTS	[326]	2.9-13

9 PRIME POWER	AIR BREATHERS	POWER UNIT	MTG INSTAL	PROPEL TANK/SYS	TEMP CONTROL	CONTROLS	TOTAL	3582
BATTERIES		35					(35)	
ENGINE TURBINE	1816	486 *	326	295	173	451	(3547)	
FUEL CELL							( )	

* INCLUDES ALTERNATORS

APU

APU WEIGHT SUBSTANTIATION

The booster APU utilizes two types of power units to provide power for the hydraulic and electrical power systems. The Oxygen/hydrogen APU is used for ascent and reentry. JP-4 is utilized by an air turbine power unit to provide power for flyback and landing. The JP-4 system is also used for ferry, testing and ground checkout.

The APU oxygen-hydrogen requirements were combined with the RCPS propellant requirements to determine the tank sizing. The weights of these tanks are coded in the RCPS system.

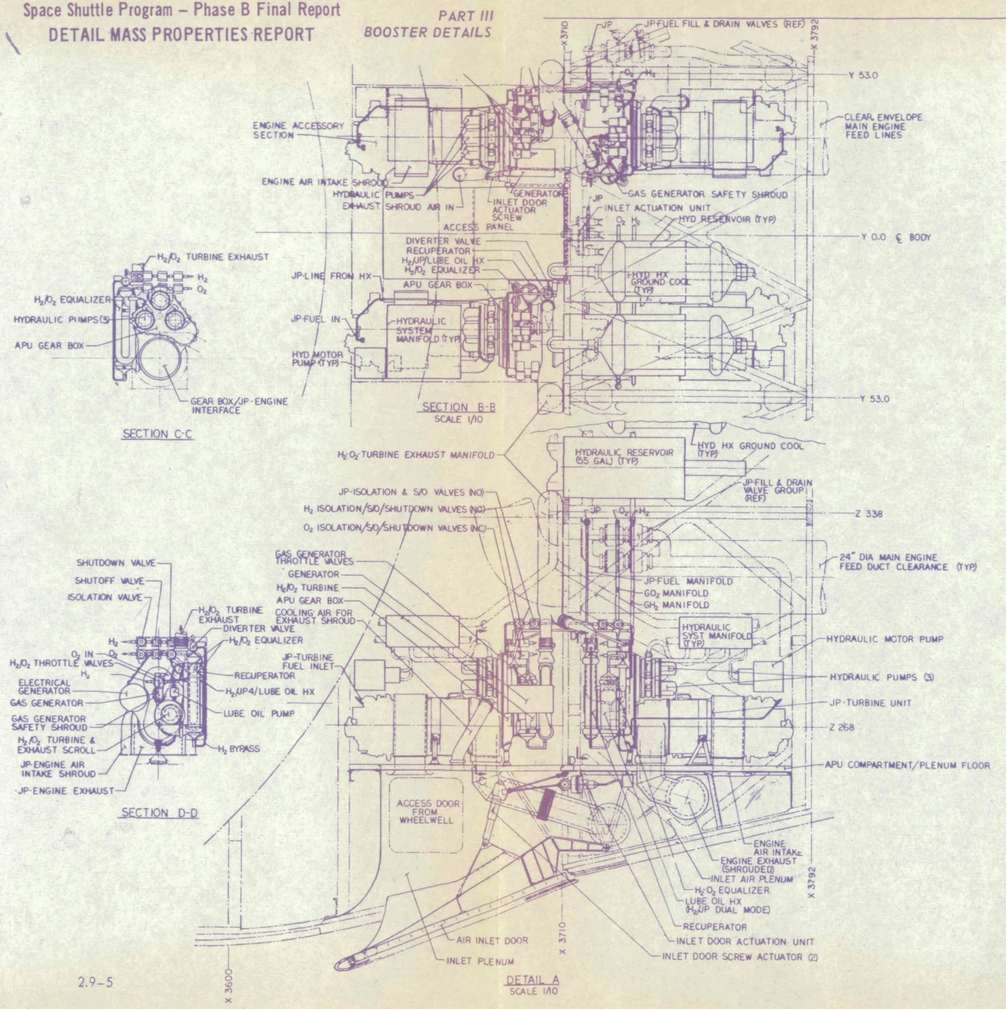
The JP-4 propellant requirements were combined with the Air-Breather requirements to size the JP-4 propellant tanks. The tank weights

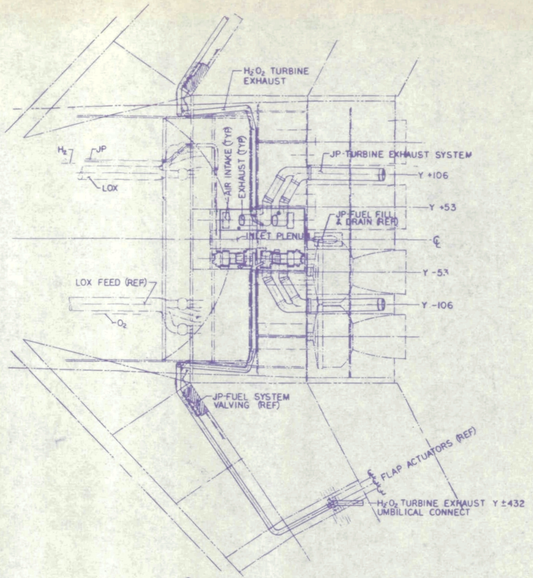
2.9-3

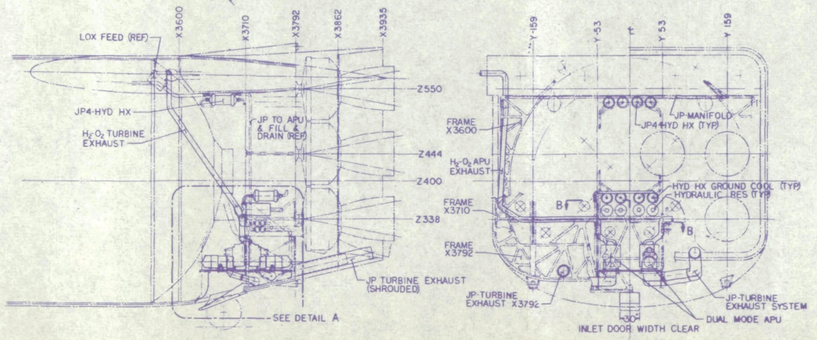
APU (cont)

were coded to the Cruise Propulsion system.

The weight of the air breathing power unit is based on the United Aircraft PT6A-27 ACES type jet engine.



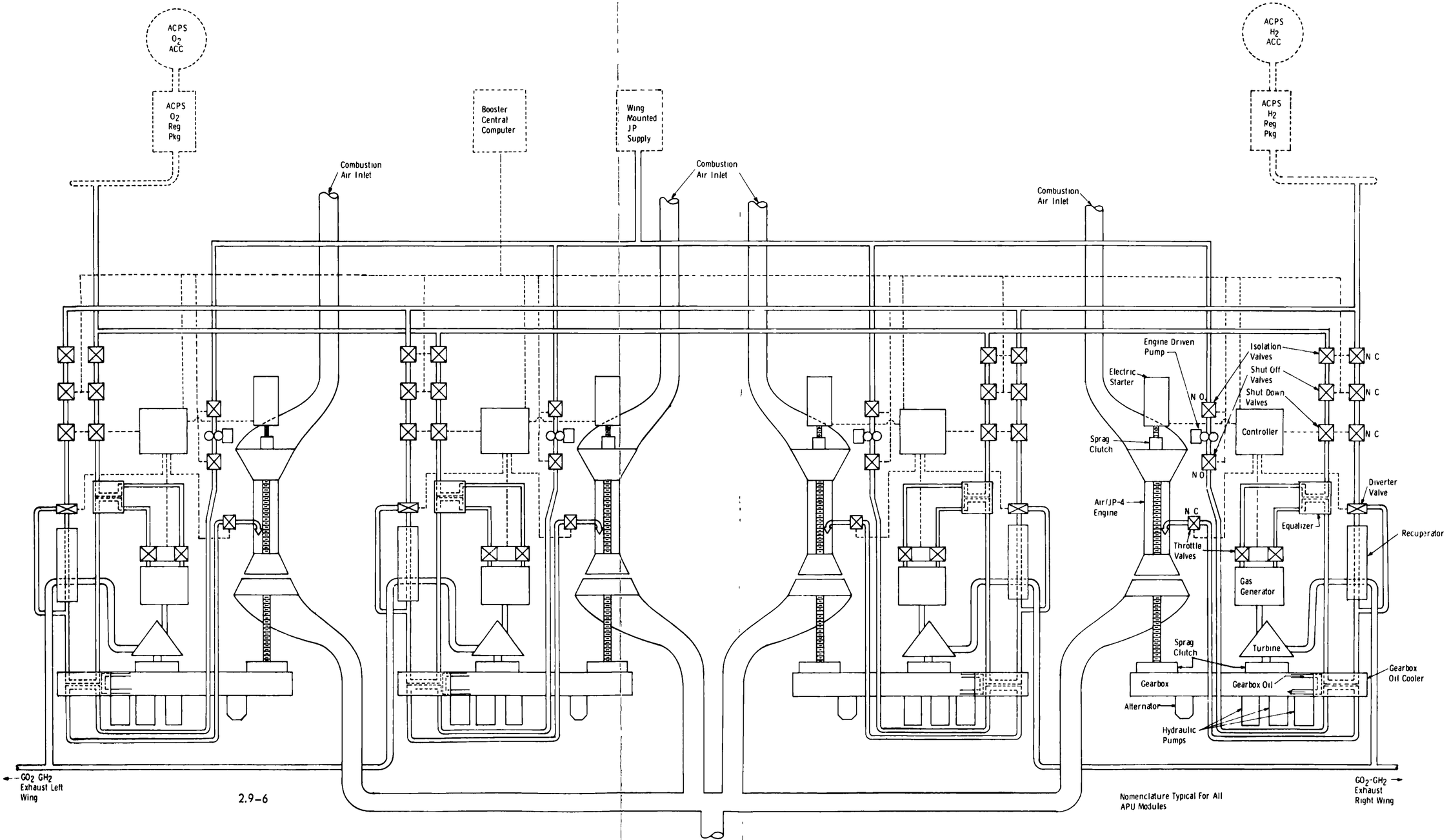




APU SYSTEM INSTALLATION

899A2020649

APU SYSTEM SCHEMATIC



H_2/O_2 APU (BASED ON AIRESEARCH MFG. CO DATA)

Gas Generator

Minimum flow = .17 lb/sec (H_2), .13 lb/sec (O_2)

Maximum flow = .75 lb/sec (H_2), .55 lb/sec (O_2)

P_c = 550 psia

T_c = 2000°R

MR = 0.75

SPC (average) = 1.9 lb/HP-HR

Weight = 5.5 lb (4 REQD)

Turbine

P_{in} = 500 psia

T_{in} = 2000°R

Speed = 70,000 rpm

Power = 715 SHP

Weight = 44 lb (4 REQ'D)

Gearbox

$Speed_{in}$ = 70,000 rpm

$Speed_{out}$ = 3 hyd. pumps @ 4500 rpm, 1 alternator @ 12,000 rpm

Weight = 98 lb (4 REQ'D)

Controller (H_2/O_2 and JP-4 combined)

Weight = 7.5 lb

Recuperator (Turbine exhaust/GH_2)

TH_{2in} = 260°R

TH_{2out} = 740°R (maximum-portion of H_2 can be bypassed)

$T_{exhaust\ in}$ = 1500°R

Weight = 33.2 (4 REQ'D)

Hydraulic Pump

P_{out} = 3000 psia

Capacity = 110 GPM

Power = 190 HP

Speed = 4500 rpm

Weight = 54 lb (12 REQ'D) CODED TO HYDRAULICS

Alternator

Power = 3 phase, 400 Hz, 60/90 KVA

Speed = 12,000 rpm

Weight = 46 lb (4 REQ'D)

DISTRIBUTION SYSTEM.

TURBINE EXHAUST LINES

MAT. = ARMCO ST. STEEL 21-6-9.

OUTSIDE DIAM = 7.0 INS.
WALL THICKNESS = .016 INS.
LENGTH = 850 INS. EACH SIDE X 2 = 1700 INS.

WEIGHT = 1700 (.100 #/IN) = 170. lbs
FITTINGS = 40% LINE WT = 68 lbs
TOTAL = 238 lbs.

MANIFOLD LINES

MAT. = ARMCO ST STEEL 21-6-9
OUT SIDE DIAM = $\frac{3}{4}$"
LENGTH = 1400 INS
WALL THICKNESS = .010 IN
WEIGHT = 1400 (.0066 #/IN) = 9 lbs
FITTINGS = 40% LINE WT = 4 lbs
TOTAL 13 lbs

COMPONENT LINES.

MAT = ARMCO ST. STEEL 21-6-9

O.D	WALL THICK	#/IN	LENGTH	WEIGHT
$3\frac{1}{2}$"	.016 ins	.0497	360 ins	18 lbs
$\frac{1}{2}$"	.010	.0045	1100 ins	5
		FITTINGS = 40% =		9.
		TOTAL =		32. lbs

2.9-9

Air Breathing APU (BASED ON AIRESEARCH MFG. CO. DATA)

Minimum JP-4 flow = .19 lb/sec

Maximum JP-4 flow = .56 lb/sec

SFC (average) = 1.16lb/HP-HR

MR = 50

Power (maximum) = 715 SHP

Output shaft speed = 35,000 rpm

Dry weight (including gearbox) = 289 lb (4 REQ'D) = 1156 lbs

Maximum diameter (envelope) = 19 in.

Maximum length (envelope) = 62 in.

CLUTCH - ESTIMATED @ 17.5 LBS (4 REQ'D) = 70 lbs

SUMMARY

AIR BREATHERS - APU [1816]

4 JP/AIR [illegible] (1156)

4 CLUTCHES (70)

[illegible]

APU INLET & EXHAUST DUCTS

INLET

FAIRING
34 in × 10 in × .1 × .101 = 3.4 lbs

CUT-OUT REINFORCEMENT
230 × 2.0 × (.100)(.101) = 4.7 lbs

2 ACTUATORS @ 20 lbs ea. = 40.0 lbs
[SAME AS AIR BREATHERS INTAKE DOOR]

2 MOTORS WITH CONTROL VALVES = 36.0 lbs
@ 18 lbs ea

TORQUE TUBE
.08 #/in × 70 in = 5.6 lbs

TOTAL = 89.7 lbs

EXHAUST

ST. STEEL ARMCO 21-6-9 DUCTING
&
TITANIUM 5AL-2.5 SN DUCTING

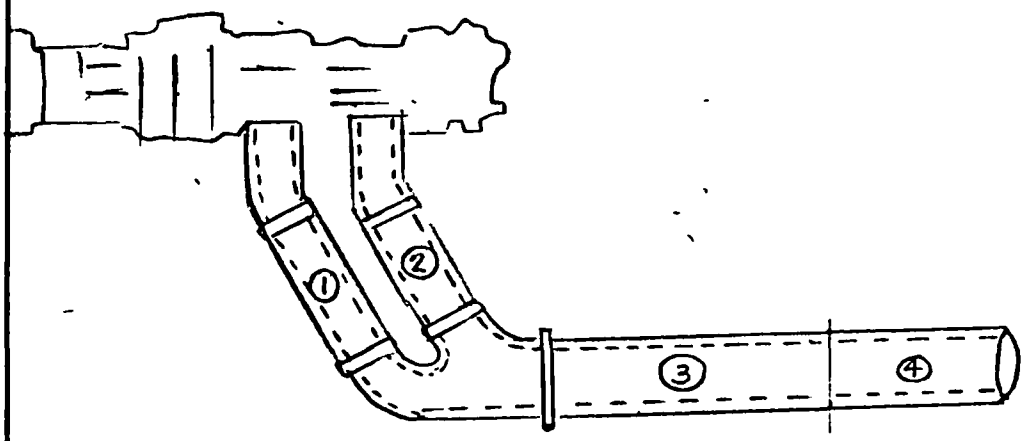
SEE SKETCH

CODE	QTY	OUTSIDE DIA. & WALL	INSIDE DIA. & WALL	LENGTH	WT-LBS.
①	2	(Ti) 14. in (.035)	(ST.) 11.5 in (.030)	90	95
②	2	(Ti) 14. in (.035)	(ST.) 11.5 in (.030)	80	83
③	2	(Ti) 20. in (.040)	(ST.) 17.0 in (.040)	120	142
④	2	(ST) 20 in (.040)	(ST.) 17.0 in (.040)	50	133
			FLANGES =		48
			2 × 12		
			8 × 3		
			TOTAL =		501
			SUPPORTS - 10% =		50

2.9-11

APU
JP TURBINE EXHAUST DUCTING

2 REQUIRED



CODE	DIAMETER INSIDE	OUTSIDE INS.
①	11.5	14.
②	11.5	14.
③	17.	20.
④	17.	20.

BATTERY. NICKEL-CADMIUM TYPE
3 AMP-HR. -120 VOLT.
WT = 35 LBS.

SUPPORTS SUPPORT WEIGHT ESTIMATED AT 10% OF EQUIPMENT WEIGHT & DUCTING.

EQUIPMENT & DUCTING = 3256 lbs

SUPPORT WT = 326 lbs

LUBE-OIL

8 GALS @ 7.6 #/GAL = 61 lbs

LUBE-OIL COOLER

4.5 LBS (4 REQ'D) = 18 lbs.
(AIRESEARCH MFG. CO. DATA)

JP-4 PROPELLANT REQUIREMENTS
FOR APU

	WEIGHT LBS.
USEABLE	1741
RESERVE 10%	174
TRAPPED RESIDUALS 2%	39
TOTAL	1954

BOOSTER BASELINE ACPS/APU PROPELLANT REQUIREMENTS

PROPELLANT INVENTORY	ACPS	APU	SERVICE	TOTAL
HYDROGEN USABLES	221	168	139	528
HYDROGEN RESERVES	6	14	-	20
HYDROGEN PUMP COOLING	5	-	-	5
HYDROGEN RESIDUALS (2%)	5	4	3	12
* H_2 ACCUMULATOR/LINE RESIDUALS	* (46)	-	-	(46)
TOTAL HYDROGEN LOADED *IN TANK.*	237	186	142	565
OXYGEN USABLES	991	126	139	1256
OXYGEN RESERVES	48	3	-	51
OXYGEN PUMP COOLING	4	-	-	4
OXYGEN RESIDUALS (2%)	21	3	3	27
* O_2 ACCUMULATOR/LINE RESIDUALS	* (213)	-	-	(213)
TOTAL OXYGEN LOADED *IN TANK.*	1064	132	142	1338

* NOT INCLUDED IN TANK SIZING

H_2 LOADED IN TANK + LINES — 611 lbs
O_2 LOADED IN TANK + LINES — 1551 lbs

2.9-15

HYDROGEN RESERVE & OXYGEN RESERVE DERIVATIONS

ACPS

H_2 = [USABLE] $221 \times 5\% = 11$ lbs

O_2 = [USABLE] $991 \times 5\% = 50$ lbs.

APU

H_2 = [USABLE] $168 \times 10\% = 17$ lbs.

O_2 = [USABLE] $126 \times 10\% = 13$ lbs.

ROOT SUM SQUARED

$H_2 = \sqrt{11^2+17^2} = \sqrt{410} = 20.2$

$O_2 = \sqrt{50^2+13^2} = \sqrt{2669} = 51.6$

ACPS

RESERVE PROP

HYDROGEN $= \frac{11^2}{11^2+17^2} \times 20.2 = \underline{\underline{6}}$ lbs

OXYGEN $= \frac{50^2}{50^2+13^2} \times 51.6 = \underline{\underline{48}}$ lbs

APU

RESERVE PROP

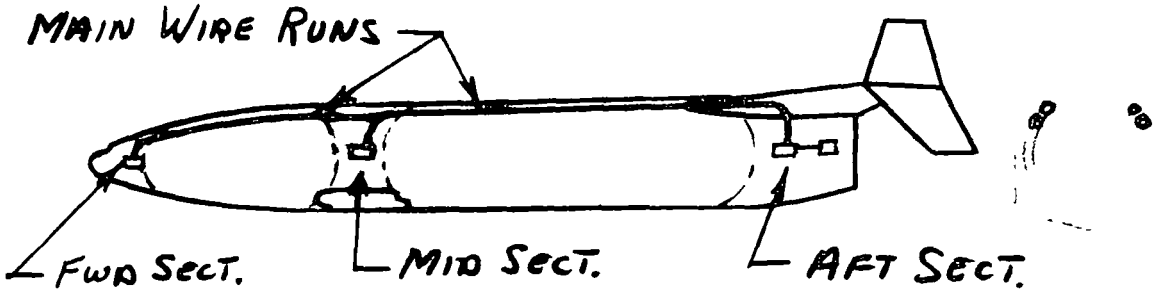
HYDROGEN $= \frac{17^2}{11^2+17^2} \times 20.2 = \underline{\underline{14}}$ lbs.

OXYGEN $= \frac{13^2}{50^2+13^2} \times 51.6 = \underline{\underline{3}}$ lbs

10. ELECTRICAL GROUP

	WEIGHT (LB)	PAGE NO.
	[1818]	
POWER CONVERSION EQUIPMENT	[192]	2.10-7
TRANSFORMER RECTIFIERS		
2 KW.	(56)	
1/2 KW.	(16)	
10 KW.	(120)	
POWER CONTROL EQUIPMENT	(484)	2.10-7
POWER CONTRACTORS	(19)	
BUS TIE BREAKERS	(29)	
GENERATOR CONTROL UNITS	(14)	
REMOTE POWER CONTROLLERS	(420)	
BUS VOLTAGE MONITORS	(2)	
POWER DISTRIBUTION CIRCUITS	[853]	2.10-7
WIRE	(742)	
WIRE-POWER MAIN CABLES	604	
WIRE-REMOTE PWR CTR/DIV.	80	
WIRE-CROSS OVER	22	
WIRE-GROUND PWR PROV.	36	
CONNECTORS	(111)	
INSTRUMENTATION	[6]	2.10-7
VOLTAGE READOUTS	(6)	
SUPPORTS	[157]	2.10-7
CLAMPS	(85)	
SUPPORT STRUCTURE	(72)	
LIGHTS	[126]	2.10-11
LANDING	(57)	
ANTI-COLLISION	(45)	
INTERIOR	(24)	

ELECTRICAL



10. ELECTRICAL	SUPPLY	CONVERSION	CONTROL UNITS		
EQUIPMENT		192	484	676	1818
DISTRIBUTION AND CONTROL CIRCUITRY				853	
UTILITY SYSTEMS				126	
SUPPORTS/INSTALLATION				163	

ELECTRICAL WEIGHT SUBSTANTIATION

ELECTRICAL SYSTEM.

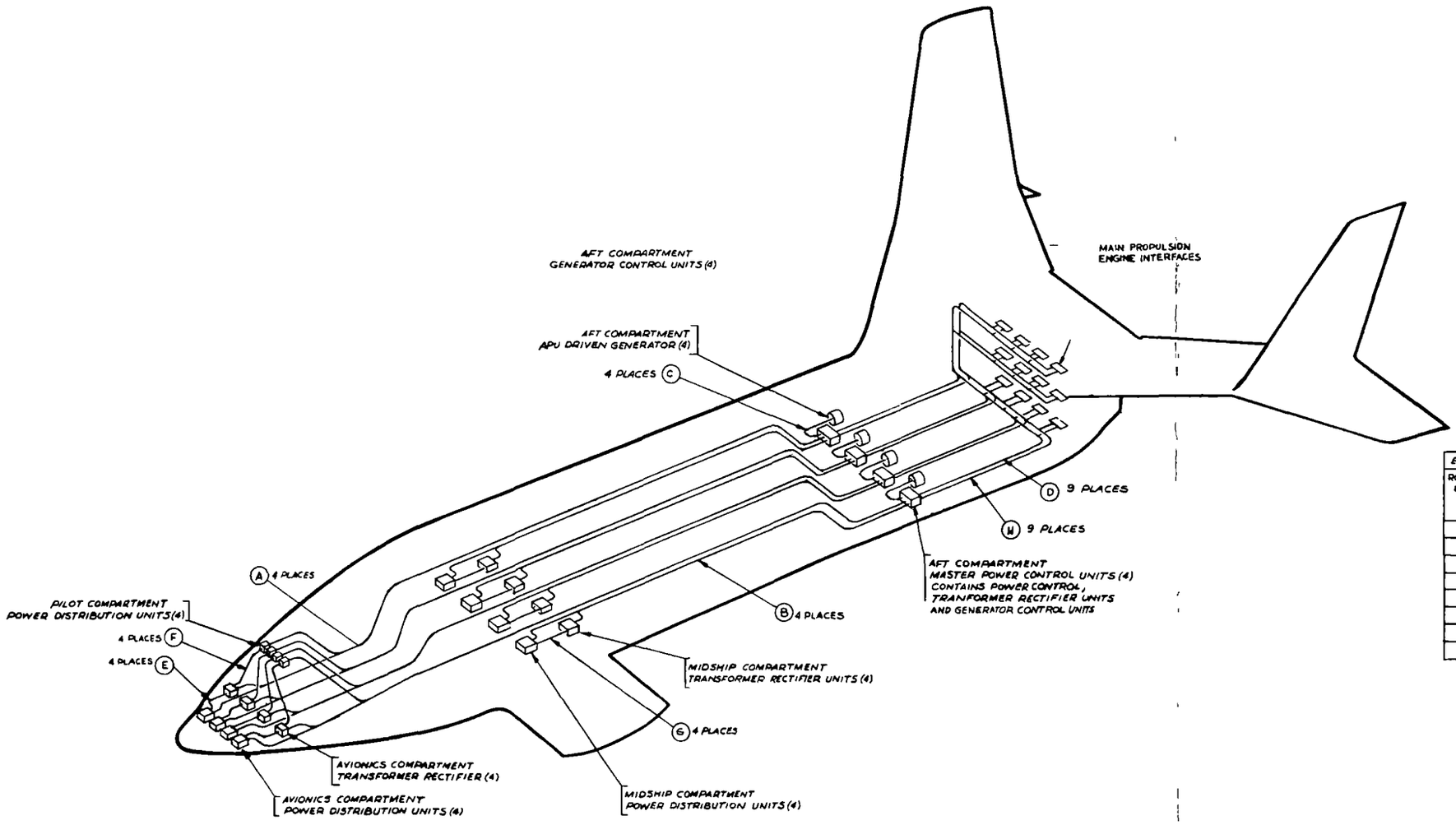
The electrical power subsystem contains the following elements: power generation, control, distribution, conditioning and fault protection. Four separate power generation, transmission and distribution subsystems are provided. Each power generation transmission and distribution subsystem is independent of the other. Electrical power is produced by four AC generators each of which is driven by a separate auxiliary power unit (APU).

Three phase AC power transmission feeders distribute the power to forward, midship and aft compartments. Transformer rectifiers in each compartment are used to convert the AC power to DC for DC requirements.

2.10-3

Both AC and DC power is routed to the power distribution units which serve as the power distribution points for the loads in each compartment. The power distribution units contain the remote power controllers which serve as power switch and circuit breaker.

Power distribution wiring is routed over the top of the vehicle between the thermal protection system and the propellant tanks to each compartment. Two of the distribution systems are routed on the left side and two on the right side. Power distribution wire weights were based on lightweight "H" film insulation wiring.



TABLE

ESTIMATED WIRE LENGTHS OF PRIMARY POWER FEEDERS

ROUTING PATH	NO OF WIRES PER PATH	LENGTH FEET	FUNCTION
A	3	250	FORWARD AC TRANSMISSION LINE
B	3	160	MIDSHIP ACTRANSMISSION LINE
C	3	50	MAIN POWER FEEDER
D	3	AVG 30	ENGINE AC POWER
E	2	5	AVIONICS DC POWER
F	2	30	PILOT COMPARTMENT DC POWER
G	2	5	MIDSHIP DC POWER
H	2	AVG 30	ENGINE DC POWER

M G WINIER
C F Shaw
J R Taylor
W A Cadle

INSTALLATION - ELECTRICAL POWER SUBSYSTEM - BOOSTER

899A2030635

1 OF 2

APU – AUXILIARY POWER UNIT
BTB – BUS TIE BREAKER
BTC – BUS TIE CONTACTOR
CB – CIRCUIT BREAKER
DIU – DIGITAL INTERFACE UNIT
GCU – GENERATOR CONTROL UNIT
GND – GROUND
GPC – GROUND POWER CONTACTOR
PDU – POWER DISTRIBUTION UNIT
RPC – REMOTE POWER CONTROLLER
PMG – PERMANENT MAGNET GENERATOR
PTC – POWER TRANSFER CONTACTOR
TR – TRANSFORMER RECTIFIER
BVM – BUS VOLTAGE MONITOR

AC GENERATOR 1
TEMPERATURE
BEARING FAILURE
GCU1
DIFF AND OVERCURRENT PROTECTION
VR
UNDERSPEED/OVERSPEED TRIP
OVER & UNDER VOLTAGE TRIP
GPC 2
PTC 2
AC GENERATOR 2
GCU 2
GPC 3
PTC 3
AC GENERATOR 3
GCU 3
GPC 4
PTC 4
AC GENERATOR 4
GCU 4
SINGLE POINT GROUND
BVM
BTC 1-2
BTC 1-4
BTC 2-3
BTC 3-4
BTB 1F
BTB 1M
BTB 1A
BTB 2F
BTB 2M
BTB 2A
BTB 3F
BTB 3M
BTB 3A
BTB 4F
BTB 4M
BTB 4A
TR 1A
PDU 1A1
PDU 1A2
TR 1M
PDU 1M
TR 1F
PDU 1F1
PDU 1F2
TR 2A
PDU 2A1
PDU 2A2
TR 2M
PDU 2M
TR 2F
PDU 2F1
PDU 2F2
TR 3A
PDU 3A1
PDU 3A2
TR 3M
PDU 3M
TR 3F
PDU 3F1
PDU 3F2
TR 4A
PDU 4A1
PDU 4A2
TR 4M
PDU 4M
TR 4F
PDU 4F1
PDU 4F2
+115 VDC
RPC
CONTROL POWER BUS 1
CONTROL POWER BUS 2
CONTROL POWER BUS 3
CONTROL POWER BUS 4
CONTROL BUS BATTERY
BATTERY SWITCH
(REF SHEET 2)
TYPICAL TR
SHUNT
CURRENT VOLTS MONITOR
DATA BUS
DIU
PDU
AFT - "A"
MIDSHIP - "M"
FORWARD - "F"

MARTIN MARIETTA CORPORATION
SCHEMATIC
BOOSTER ELECTRICAL POWER SYSTEM
(POWER DISTRIBUTION)
04236 899A2030608
1 OF 2

POWER CONVERSION EQUIPMENT

TRANSFORMER RECTIFIERS

	NO REQD	PWR	DIMENSIONS	WT-EA	TOTAL WT. LBS.
FWD-SECT.	4	2KW	$8\times4\times6\frac{1}{2}$	14	56
MID-SECT.	4	$\frac{1}{2}$KW	$6\times3\times5\frac{1}{2}$	4	16
AFT-SECT.	4	10 KW	$14\times6\times13\frac{1}{4}$	30	120
			TOTAL PWR CONVERS. EQUIP.		192 lbs

POWER CONTROL EQUIPMENT

NO		WT-EA	TOTAL WT LBS
12	PWR CONTACTORS	1.6	19
12	BUS TIE BREAKERS	2.4	29
4	GENERATOR CONTROL UNITS	3.5	14
700	REMOTE PWR CONTROLLERS	0.6	420
4	BUS VOLTAGE MONITORS	0.5	2
	TOTAL PWR CONT EQUIP.		484 lbs

INSTRUMENTATION

NO		WT-EA	TOTAL
24	VOLTAGE READOUTS	0.25	6 lbs

SUPPORTS

	TOTAL
CLAMPS = 10% WIRE WEIGHT =	85
SUPPORTS = 10% EQUIPMENT WEIGHT =	72

POWER DISTRIBUTION CIRCUITS

WIRE POWER MAIN CABLES

AREA	WIRE GAUGE	NO. OF WIRES	REDUNDANCY	LENGTH FT	WT LB/FT	LB
FWD SECT	#6	4	x 4 = 16	273	.093	406
MID-SHIP SECT	#8	4	x 4 = 16	180	.061	176
AFT SECT	#12	4	x 4 = 16	60	.0225	22
					TOTAL CABLE WIRE	604

WIRE REMOTE PWR CONTROL UNITS TO DIGITAL INTERFACE UNITS

#24	35,000 FT	.0023	80

WIRE CROSS-OVER

#4	150 FT	.148	22

WIRE PROVISION FOR UMBILICAL GROUND PWR.

#4	240 FT	.148	36

TOTAL WIRE WT = [742]

CONNECTORS = 111
15%-WIRE WT

POWER DIST. CIRCUITS TOTAL = 853

MARTIN MID. STD.	DESCRIPTION	LBS/FT
*MMS E0891629	+16 GA, 1 COND, S.	.0175
*MMS E0891829	+18 GA, 1 COND, S.	.0134
*MMS E0892029	+20 GA, 1 COND, S.	.0103
*MMS E0892229	+22 GA, 1 COND, S.	.0092
MMS E1150115	COAX, CABLE	.1233
MMS E3845319	20 GA, 1 COND, S.	.0240
MMS E3845329	20 GA, 2 COND, S.	.0414
MMS E3846129	22 GA, 2 COND, S.	.0362
MMS E3871929	+20 GA, 2 COND, S.	.0190
MMS E3872329	+22 GA, 2 COND, S.	.0134
MMS E3930329	12 GA, 2 COND, S.	.0837
MMS E3931129	16 GA, 2 COND, S.	.0462
MMS E3931929	20 GA, 2 COND, S.	.0298
MMS E3932329	22 GA, 2 COND, S.	.0233
MMS E4191122	24 GA, 2 COND, S.	.0163
MMS E4592112	20 GA, S.	.0340
STM E6372129	+16 GA, 2 COND, S.	.0295
STM E6372329	+20 GA, 2 COND, S.	.0182
STM E6372339	+20 GA, 3 COND, S.	.0264
STM E6372429	+22 GA, 2 COND, S.	.0148
*STM E7162209	+22 GA, 1 COND, S.	.0092
*STM E7180009	+ 0 GA, 1 COND, U.S.	.3770
*STM E7180109	+ 1 GA, 1 COND, U.S.	.3770
*STM E7180209	+ 2 GA, 1 COND, U.S.	.2360
*STM E7180409	+ 4 GA, 1 COND, U.S.	.1480 ←
*STM E7180609	+ 6 GA, 1 COND, U.S.	.0930 ←
*STM E7180809	+ 8 GA, 1 COND, U.S.	.0610 ←
*STM E7181009	+10 GA, 1 COND, U.S.	.0374
*STM E7181209	+12 GA, 1 COND, U.S.	.0225 ←
*STM E7181409	+14 GA, 1 COND, U.S.	.0140
STM E7181609	+16 GA, 1 COND, U.S.	.0089
*STM E7181809	+18 GA, 1 COND, U.S.	.0058
STM E7182009	+20 GA, 1 COND, U.S.	.0048
STM E7182209	+22 GA, 1 COND, U.S.	.0033
*STM E7182409	+24 GA, 1 COND, U.S.	.0023 ←
STM E7182609	+26 GA, 1 COND, U.S.	.0017

MARTIN MIL. STD.	DESCRIPTION	LBS/FT
*STM E7181409	+14 GA, 1 COND, S.	.0230
*STM E7181209	+12 GA, 1 COND, S.	.0340
STM E7191609	+16 GA, 1 COND, S.	.0160
*STM E7191809	+18 GA, 1 COND, S.	.0134
STM E7192009	+20 GA, 1 COND, S.	.0107
STM E7192209	+22 GA, 1 COND, S.	.0078

* This value is an Engineering estimate (from Material Specification).

DESCRIPTION - U.S. - UNSHIELDED
S. - SHIELDED
+ - LIGHT WEIGHT

2.10-10

LIGHTS

[126]

LANDING LIGHTS (DC-10 DATA)	(57)
LAND & TAXI	36
WIRING	16
SUPTS	5
ANTI-COLLISION LIGHTS (DC-10 DATA)	(45)
INTERIOR LIGHTS (B-70 DATA)	(24)

11. HYDRAULIC SYSTEM	7,282 WEIGHT (LB)	PAGE NO.
POWER SUPPLY (PUMP-MANIFOLD ASSY)	(900)	2.11-3
DISTRIBUTION CONTROL CENTER	(5,879)	2.11-3
RESERVOIRS	1,136	2.11-36
DISTRIBUTION MANIFOLDS	954	2.11-3
CHECK VALVES	105	2.11-3
FILTERS	123	2.11-3
LINES, FITTINGS, & INSTALLATION	2,270	2.11-4
RLS SHUTOFF VALVES	104	2.11-3
BULKHEAD CONNECTIONS & FITTINGS	21	2.11-3
NC RETURN LINE SOL. SHUTOFF VALVES	6	2.11-3
HEAT EXCHANGERS (GSE)	360	2.11-3
HEAT EXCHANGERS (FLIGHT)	800	2.11-3
AUXILIARY SYSTEMS (PUMP)	(132)	2.11-21
SUPPORTS & INSTALLATION	(371)	2.11-4

11. HYDRAULIC

	PRIMARY (7282)	UTILITY (0)	EMERG (0)	7282
POWER SUPPLY	900			
DISTRIBUTION CONTROL CTR	5879			
TEMPERATURE CONTROL SY	0			
AUXILIARY SYSTEMS	132			
SUPPORTS, INSTALLATION	371			

HYDRAULIC SYSTEM COMPONENTS

HYDRAULIC PUMP & MANIFOLD – BASED ON ABEX AP40V-1.

RESERVIOR – SEE PAGE 2.11-36.

DISTRIBUTION MANIFOLD – ESTIMATED FROM LAYOUT.

CHECK VALVES, FILTERS, RLS S/O VALVES, NC RETURN S/O VALVES – ESTIMATED RELATIVE TO EXISTING HARDWARE.

AUXILIARY PUMP – SEE PAGE 2.11-21

LINES, FITTINGS & INST. – SEE PAGE 2.11-4 AND ANALYSIS BEGINNING ON PAGE 2.11-6

BULKHEAD CONNECTIONS & FITTINGS – AEROQUIP SERIES 145

HEAT EXCHANGERS – HAMILTON STANDARD ESTIMATE

SUPPORTS & INSTALLATION – SEE PAGES 2.11-4 AND 2.11-44

HYDRAULIC SYSTEM COMPONENTS

ITEM	WEIGHT EACH	QUANTITY	WEIGHT TOTAL
HYDRAULIC PUMP & MANIFOLD	75	12	900
RESERVOIR	284	4	1136
DISTRIBUTION MANIFOLD	238	4	954
CHECK VALVES	26.2	4	105
FILTERS	30.8	4	123
AUXILIARY PUMP (ELECT.)	33	4	132
LINES, FITTINGS & INST.	567.6	4	2270
RLS SHUTOFF VALVES	6.5	16	104
BULKHEAD CONNECTIONS & FITTINGS	2.1	1	2.1
NC RETURN LINE SOL. S/O VALVES	2	3	6
HEAT EXCHANGER (GSE)	90	4	360
HEAT EXCHANGER (FLIGHT)	200	4	800
SUPPORTS & INSTALLATION	—	—	371
TOTAL DRY WEIGHT			7282 LB

WEIGHT FACTORS HYDRAULIC SYSTEMS

THREADED FITTINGS 67% OF LINE WT. FOR FITTINGS, SUPTS, ATTACH.

DC-8F	58.9%
C-124C	57.3%
C-133B	82.5%

} AVERAGE 66.2%

THREADED FITTINGS FACTOR	67%
LESS THREADED FITTING PORTION (67% x .30)	−20.1%
ADD BRAZED FITTING PORTION	+3.2%
FACTOR FOR INSTALLATION - BRAZED FITTINGS	50.1%
* NOMINAL VALUE	50%

HYDRAULIC EQUIPMENT INSTALLATION FACTOR 8%

FOR RESERVOIRS, ACCUMULATORS & PUMPS

DC-8F	7.3%
C-124C	6.6%
C-133B	9.7%

} AVERAGE 7.9%

* THIS STUDY ASSUMED THE BRAZED FITTINGS FACTOR.

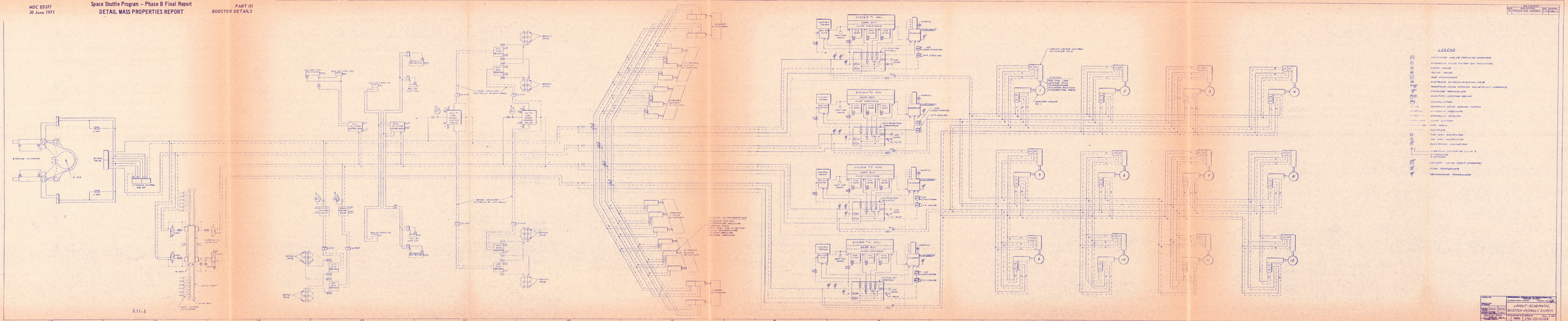
HYDRAULIC SYSTEM

SUPPORTS AND INSTALLATION

DRY SYSTEM	6911 LB
LESS LINES, FITTINGS & INSTALLATION	- 2270
TOTAL REQUIRING SUPT. & INSTALL.	4641 LB

SUPPORTS & INSTALLATION = .08 X 4641 = 371 LB

(SEE PAGE 3.11-3 FOR WEIGHT FACTOR)


LEGEND
SWITCHING VALVE (PRESSURE ENERGIZED)
HYDRAULIC FLUID SYSTEM (AS INDICATED)
CHECK VALVE
RELIEF VALVE
HEAT EXCHANGER
ELECTRICAL INTERCONNECTION CABLE
PRESSURE LEVEL SENSING VALVE (BURST DIAPHRAGM)
PRESSURE TRANSDUCER
QUANTITY LIMITING DEVICE
ACCUMULATOR
PRESSURE LEVEL SENSING SWITCH
HYDRAULIC PRESSURE
HYDRAULIC RETURN
FLOW SWITCHES
CASE DRAIN
ELECTRICAL
TWO WAY RESTRICTOR
ONE WAY RESTRICTOR
ELECTRICAL CONNECTOR
HYDRAULIC SYSTEM AS LU OR A
PRESSURE
TEMPERATURE
GAUGE (FILLED TIGHT DIAPHRAM)
FLOW TRANSDUCER
TEMPERATURE TRANSDUCER
SYSTEM #1 ACC.
SYSTEM #2 ACC.
SYSTEM #3 ACC.
SYSTEM #4 ACC.
LEAK BUS
HIGH PRESSURE
LOW PRESSURE
RETURN
HYDRAULIC MANIFOLD
GSE CONNECTION
GSE COOLING
ACTUATOR MANIFOLD NO. 1
ACTUATOR MANIFOLD NO. 2
ACTUATOR MANIFOLD NO. 3
ACTUATOR MANIFOLD NO. 4
THRUST VECTOR CONTROL ACTUATOR (TVC)
FORWARD HEAT SHIELD CLOSEOUT
FORWARD SKIRT
FORWARD ATTACH
FORWARD ACTUATOR
AFT SKIRT
AFT ATTACH
AFT ACTUATOR
NOZZLE ACTUATOR
NOZZLE EXTENSION
NOZZLE
ENGINE ACTUATOR
ENGINE
GIMBAL BEARING
GIMBAL
ENGINE MOUNT
ENGINE THRUST STRUCTURE
ENGINE THRUST MEMBER
ENGINE THRUST MEMBER
ENGINE THRUST MEMBER

HYDRAULIC ANALYSIS

3.1 Ground Rules
3.2 Tubing Analysis
3.3 Booster Configuration
3.4 Line Sizing Analysis
3.5 Actuator Weight and Volume Summary
3.6 Actuator Line Run Weight and Volume Summary
3.7 Power System Line and Fluid Weight Summary
3.8 Reservoir Sizing Study and Summary
3.9 System Weight Break Down Analysis

3.1 Ground Rules

The following ground rules apply to this weight analysis.

3.1.1 Four Hydraulic systems are to be used.

3.1.2 Max flow rates for TVC are to be summed.

3.1.3 Max flow rates for elevons and rudder are root sum square (RSS).

3.1.4 After transition, one elevon actuator will be by passed (not used).

3.1.5 Fail Safe actr load capability shall be 100% during reentry.

3.1.6 Hydraulic line sizes shall be sized to limit flow to approximately 20 feet per second.

3.1.7 Hydraulic supply pressure and return lines shall be made of the following materials:

All high pressure lines; titanium
All TVC return lines; titanium
All non critical return lines; Aluminum

3.1.8 Line fitting factor will be 1.50.

3.1.9 Weights previously used for DC-10 related components still are good.

3.1.10 Hydraulic Fluid is MIL-H-5606.

3.1.11 Bulk Modulous of fluid is 164,200 psi.

3.2.1

This Tabulation of Tubing weights was made to show weights related to larger sizes than shown in the following referenced tabulation. Also included is the fitting factor 1.50 (Ground rule 3.1.8). The specific weight of the 3AL-2.5V Titanium material was 0.162 lb/in^3 and 0.030 for the hydraulic fluid.

The Material area multiplied by the factor 2.34 gives the empty tubing weight per ft.

$$A \text{ in}^2 \times 1.50 \text{ (fitting factor)} \times \frac{12 \text{ in}}{\text{ft}} \times 0.162 \frac{\text{lb}}{\text{in}^3} = A \times 2.34 \frac{\text{lb}}{\text{ft}}$$

Likewise, fluid weight per foot is

$$\text{I.D.A in}^2 \times \frac{12 \text{ in}}{\text{ft}} \times 0.03 \frac{\text{lb}}{\text{in}^3} = \text{I.D.A} \times 0.36 \frac{\text{lb}}{\text{ft}}$$

which gives a factor 0.36 which, when multiplied by the tubing inside cross sectional area gives fluid weight per foot.

The wall thickness of the tubing was determined by the following 3.2.1 tabulation or the equation $t = 0.045D$ for min t.

3.2.1 TITANIUM TUBING

Tubing Tabulation

TUBING O.D (in)	WALL t (in)	in Σt	I.D. in	O.D. A. in²	I.D. A. in²	MAT'L A in²	A×2.34 EMPTY WT/FT lb	A×0.36 FLUID WT/FT lb
0.375	0.020	0.040	0.335	0.110	0.088	0.022	.0515	.0317
0.4375	0.020	0.040	0.396	0.151	0.123	0.028	.0656	.0443
0.500	0.024	0.048	0.452	0.196	0.161	0.035	.0820	.0580
0.625	0.032	.064	0.561	0.307	0.247	0.060	.140	.0889
0.750	0.035	.070	0.680	0.442	0.363	0.079	.185	.1307
0.875	0.042	.084	0.791	0.602	0.491	0.111	.260	.1768
1.000	0.049	.098	0.902	0.785	0.639	0.146	.342	.2300
1.125	0.052	.104	1.021	0.994	0.819	0.175	.410	.2948
1.250	0.058	.116	1.134	1.227	1.010	0.217	.508	.3636
1.375	0.062	.124	1.251	1.485	1.229	0.256	.600	.4424
1.500	0.070	.140	1.360	1.767	1.453	0.314	.735	.5231
1.625	0.076	.150	1.475	2.074	1.708	0.366	.857	.6149
1.750	0.079	.158	1.592	2.405	1.991	0.414	.970	.7168
1.875	0.085	.170	1.705	2.761	2.283	0.478	1.120	.8219
2.000	0.090	.180	1.820	3.1416	2.602	0.540	1.263	.9367
2.125	0.096	.192	1.933	3.545	2.936	0.609	1.425	1.0570
2.250	0.101	.202	2.048	3.976	3.300	0.676	1.582	1.1880
2.375	0.107	.214	2.161	4.430	3.667	0.763	1.795	1.3201
2.500	0.113	.226	2.274	4.909	4.061	0.848	1.984	1.4620
2.625	0.118	.236	2.389	5.412	4.486	0.926	2.165	1.6150
2.750	0.124	.248	2.502	5.940	4.925	1.015	2.375	1.7730

(3.2.1 CONT)

TITANIUM ALLOY (3AL-2.5V) TUBING FOR PRESSURE LINES

3000 PSI	OPERATING	t = 0.045D = MIN WALL
4000 PSI	OPERATING	t = 0.06 D = MIN WALL

FOR HANDLING -.016 WALL THICKNESS IS MINIMUM USED

REFERENCE TABULATION

SYSTEM PRESSURE	TUBE O.D.	WALL (INCHES)	WEIGHT EMPTY (LB/FT)	WEIGHT FULL (LB/FT)	MIN WALL
3000	.250	.016	.0228	.0372	.011
4000		.016	.0228	.0372	.015
3000	.3125	.016	.0283	.0516	.014
4000		.020	.0360	.0577	.019
3000	.375	.020	.0444	.0756	.017
4000		.024	.0516	.0830	.023
3000	.4375	.020	.0516	.0970	.020
4000		.026	.0660	.1180	.027
3000	.500	.024	.0708	.1232	.023
4000		.032	.0914	.1468	.030
3000	.5625	.026	.0865	.1610	.026
4000		.035	.1140	.1835	.034
3000	.625	.032	.1175	.2075	.029
4000		.038	.1380	.2240	.038
3000	.750	.035	.1545	.2870	.034
4000		.049	.2120	.3340	.045
3000	.875	.042	.2160	.3548	.040
4000		.052	.2640	.4350	.053
3000	1.000	.049	.2880	.5200	.045
4000		.065	.3760	.5910	.060
3000	1.125	.052	.3440	.6430	.051
4000		.072	.4690	.7440	.068
3000	1.250	.053	.4272	.7944	.057
4000		.078	.5652	.9072	.075

3.2.1 ALUMINUM TUBING

TUBING O.D (IN)	WALL t (in)	in 2t	I.D. in	O.D.A in²	I.D.A in²	MAT'L A in²	A x 1.80 EMPTY WT/FT lb	A x 0.36 FLUID WT/FT lb
0.375	0.016	0.032	0.343	.111	.092	.019	.0343	.0331
0.4375	0.016	0.032	0.405	.150	.129	.021	.0378	.0464
0.500	0.018	0.036	0.464	.196	.169	.027	.0486	.0608
0.625	0.022	0.044	0.581	.306	.264	.042	.0760	.0950
0.750	0.026	0.052	0.698	.442	.379	.063	.1134	.1364
0.875	0.032	0.064	0.811	.602	.517	.085	.1530	.1861
1.000	0.035	0.070	.930	.785	.679	.106	.1908	.2440
1.125	0.042	0.084	1.041	.994	.849	.145	.2610	.3656
1.250	0.049	0.098	1.152	1.227	1.042	.185	.3330	.3751
1.375	0.049	0.098	1.277	1.485	1.280	.205	.3690	.4601
1.500	0.052	0.104	1.396	1.767	1.530	.237	.4270	.5508
1.625	0.062	0.124	1.501	2.074	1.770	.304	.5470	.6372
1.750	0.062	0.124	1.626	2.405	2.080	.325	.5850	.7488
1.875	0.070	0.140	1.735	2.761	2.360	.401	.7220	.8496
2.000	0.072	0.144	1.856	3.142	2.700	.442	.7960	.9720
2.125	0.075	0.150	1.975	3.545	3.060	.485	.8730	1.1016
2.250	0.079	0.158	2.092	3.976	3.440	.536	.9652	1.2384
2.375	0.084	0.168	2.207	4.430	3.830	.600	1.0800	1.3788
2.500	0.088	0.176	2.324	4.909	4.230	.679	1.2220	1.5228
2.625	0.092	0.184	2.441	5.412	4.676	.736	1.3250	1.6524
2.750	0.097	0.194	2.556	5.940	5.130	.810	1.4600	1.8468

3.2.2

This tabulation of tubing weights was made to show the weights related to larger sizes than shown in the following referenced tabulation. (It is expected that these larger sizes of tubing will be available during the production period of the space shuttle program.) Also included is the fitting factor 1.50 (ground rule 3.1.8). The specific weights used for material are: AL = 0.10 lb/in^3; Hydraulic Fluid = 0.030 lb/in^3.

Material Factor: The material area x 1.80 = tubing with MAT'L A in^2 x 1.50 x $\frac{12 \text{ in}}{\text{ft}}$ x 0.10 $\frac{lb}{in^3}$ = A x 1.80 $\frac{lb}{ft}$ giving the factor 1.80

Fluid Factor: (Same as for 3.2.1)

Wall Thickness: The wall thickness of the tubing was determined by the following referenced tabulation or by the equation t = 0.035D = MIN WALL.

3.2.2 ALUMINUM ALLOY (6061-T6) TUBING FOR RETURN LINES

		WALL THICKNESS EQUATION
3000 PSI	OPERATING	t = .035D = MIN WALL
4000 PSI	OPERATING	t = .046D = MIN WALL

FOR HANDLING -.016 WALL THICKNESS IS MINIMUM USED

REFERENCED TABULATION

SYSTEM PRESSURE	TUBE O.D.	WALL (INCHES)	WEIGHT EMPTY (LB/FT)	WEIGHT FULL (LB/FT)	MIN WALL
3000	.250	.016	.0144	.0276	.009
4000		.016	.0144	.0276	.012
3000	.3125	.016	.0180	.0408	.011
4000		.016	.0180	.0408	.015
3000	.375	.016	.0216	.0552	.013
4000		.018	.0240	.0570	.017
3000	.4375	.016	.0252	.0720	.015
4000		.020	.0312	.0768	.020
3000	.500	.018	.0288	.0910	.018
4000		.025	.0444	.1020	.023
3000	.5625	.020	.0408	.1185	.020
4000		.028	.0576	.1308	.026
3000	.625	.022	.0456	.1428	.022
4000		.035	.0780	.1656	.029
3000	.750	.026	.0708	.2100	.026
4000		.035	.0948	.2268	.035
3000	.875	.032	.1020	.2892	.031
4000		.042	.1320	3108	.041
3000	1.000	.035	.1272	.3744	.035
4000		.049	.1752	.4080	.046
3000	1.125	.042	.1730	.4860	.040
4000		.052	.2170	.5088	.052
3000	1.250	.049	.2280	.6101	.044
4000		.058	2690	6363	.058
3000	1.50	.052	.2239	.8479	
3000	1.75	.065	.4129	1.172	
3000	2.00	.072	.5231	1.520	

3.2.3

The Flow vs. Tubing Size Tabulation relates tubing size to the flow rate in gpm to produce the limiting flow rate of 20 ft. per sec (ground rule 3.1.6) in order to limit surge effects.

The area of Tubing I.D. multiplied by the 62.5 factor gives this flow rate. The factor was derived in the following manner:

$$(\text{Tubing I.D.A } \text{in}^2) \times \left(\frac{20 \text{ ft}}{\text{sec}}\right) \times \left(\frac{12 \text{ in}}{\text{ft}}\right) \times \left(\frac{60 \text{ sec}}{\text{min}}\right) \times \frac{1}{231} \frac{\text{gal}}{\text{in}^3} \simeq$$

$$\underline{\underline{62.5 \times A \frac{\text{gal}}{\text{min}}}} \text{ giving the factor 62.5}$$

As reference material, 15 ft/sec flow rates are shown as well as the pressure drop per foot at 100° F operating temperature obtained from the flow vs. ΔP functions shown in para. 3.2.4.

3.2.3 FLOW vs. TUBING SIZE

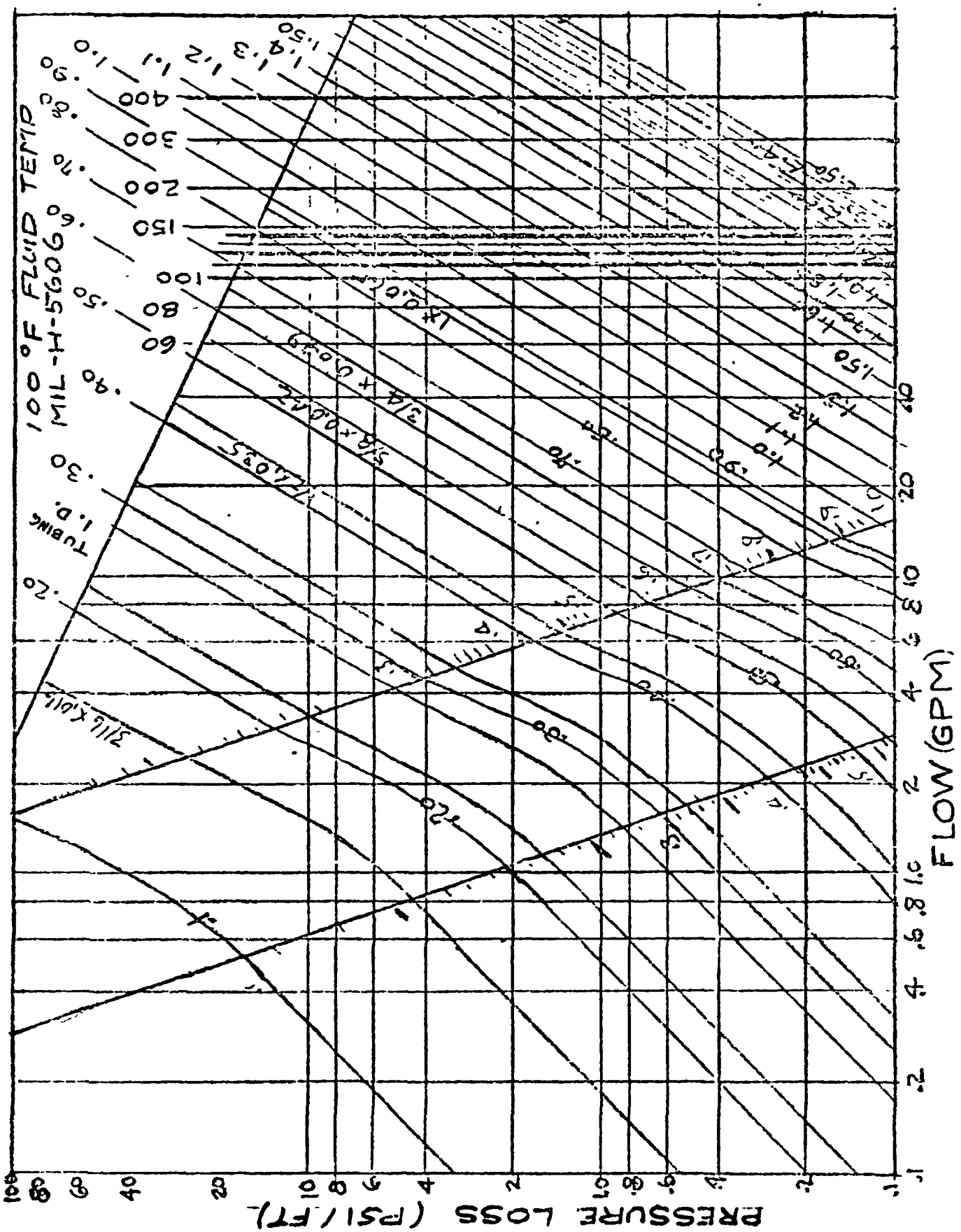
62.5

TUBING OD		WALL	I.D	AREA	X FACTOR 20 FT/SEC FLOW RATE (GPM)	REF 15 FT/SEC	ΔP/FT 20	ΔP/FT 15
.375		.020 .016	.335	0.0882	5.50	4.12	3.0	1.8
0.500		.024 .018	0.452	0.161	10.00	7.53	2.20	1.50
0.625		.032 .022	.561		15.40	11.50	1.75	1.00
0.750		.035 .026	0.680	0.363	22.70	17.00	1.30	0.85
0.875		.042 .032	0.791	0.492	30.70	23.00	1.10	0.80
1.000		.049 .035	0.902	0.635	39.60	29.60	0.85	0.70
1.125		.052 .042	1.021	0.823	51.50	38.60	0.85	0.55
1.250		.058 .049	1.134	1.010	63.20	47.40	0.80	0.50
1.375		.062	1.251	1.225	76.50	57.30	0.70	0.40
1.500		.070 .052	1.360	1.450	90.70	68.00	0.63	0.35
1.625		.075 .057	1.485	1.730	108.00	81.00	0.55	0.30
1.750		.079 .065	1.592		124.50	93.50	0.47	0.28
1.875		.085 .066	1.705	2.270	142.00	106.50	0.43	0.26
2.000		.090 .072	1.820	2.600	163.00	122.00	0.42	0.24
2.125	.0745	.096	1.933	2.950	184.00	138.00	0.39	0.23
2.250	.0789	.101	2.049	3.300	206.00	154.00	0.37	0.22
2.375	.0832	.107	2.161	3.670	230.00	172.00	0.34	0.21
2.500	.0876	.113	2.274	4.060	254.00	190.00	0.32	0.20
2.625	.092	.118	2.389	4.480	286.00	210.00	0.30	0.19
2.750	.0965	.124	2.502	4.900	306.00	230.00	0.27	0.18

3.2.4

These functions are shown in the MDAC Fluid Power Manual except that they were extrapolated out to the larger sizes shown. It was reasoned that sufficient accuracy would be achieved in this manner for the weight analysis study.

3.2.4. FLOW VS PRESSURE LOSS



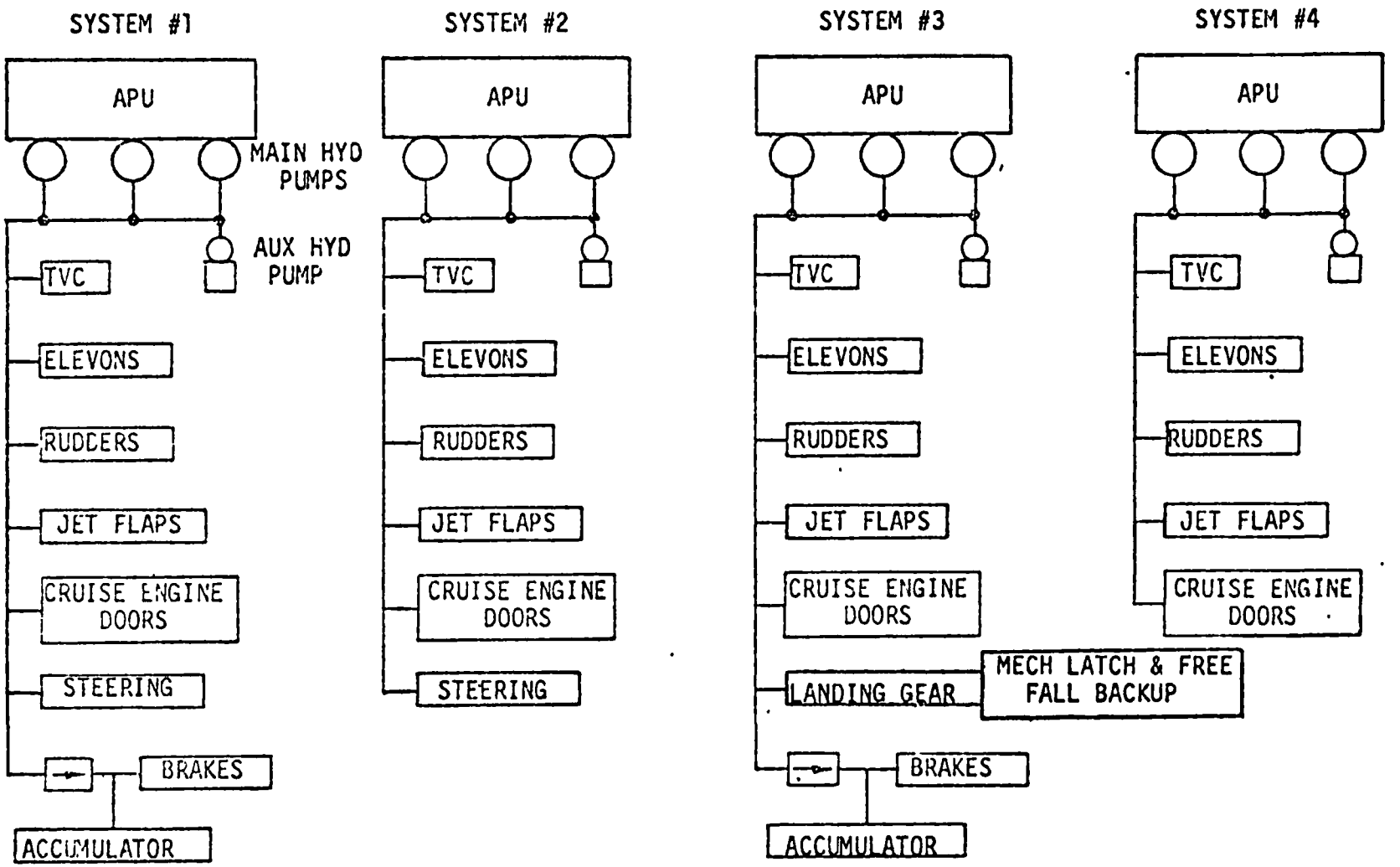
3.3 Booster Hydraulic System Configuration

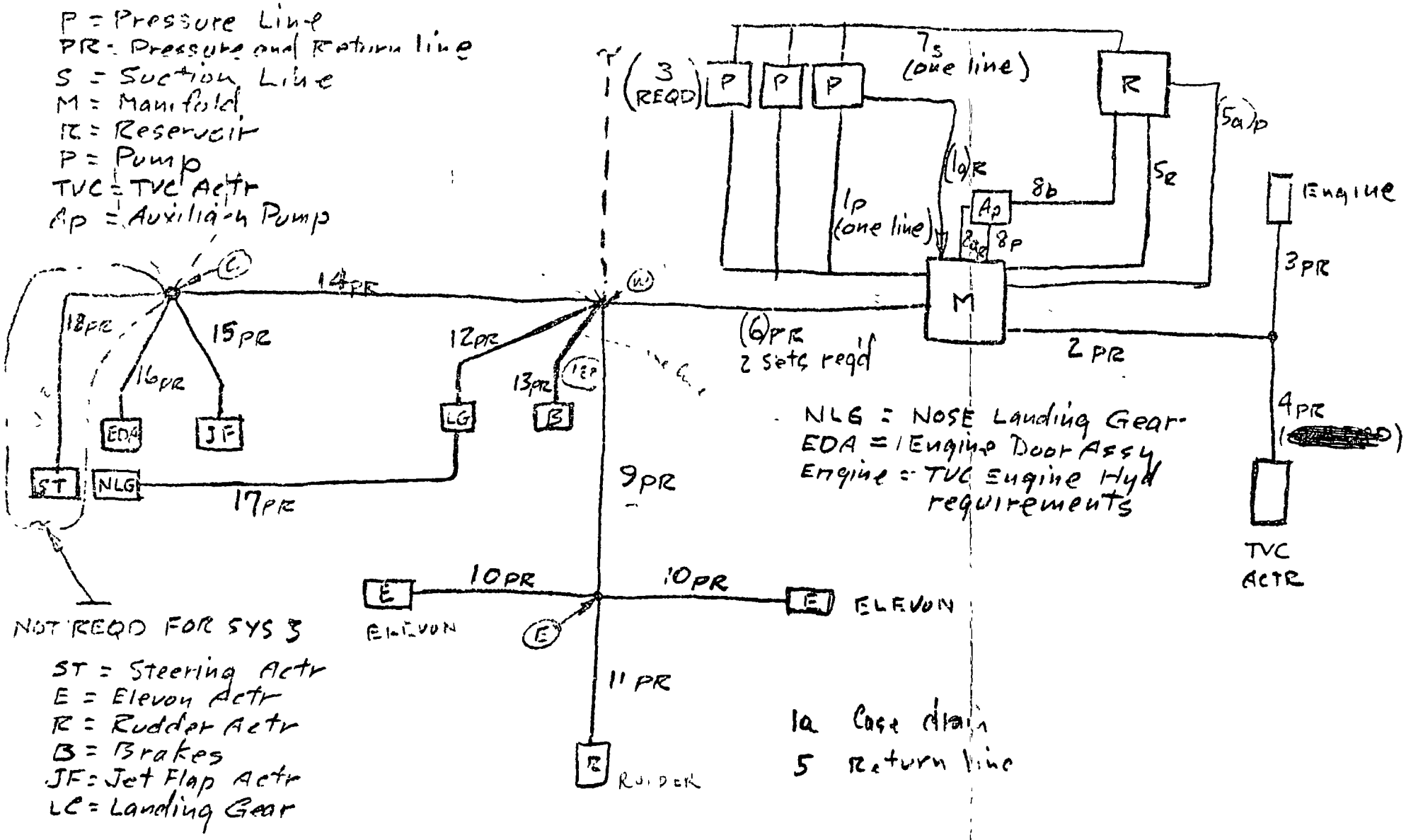
This section describes the hydraulic system. Block diagram 3.3.1, Booster Configuration 20 Hydraulic System shows four complete hydraulic systems (1, 2, 3 and 4) with associated system equipment.

The 3.3.2 Hydraulic System Line Schematic shows line runs (numbered) which will exist in the booster either as single or multiple tube assemblies. The length of these tube assemblies was determined by scaling the length from the configuration 20B General Arrangement drawing using the 3.3.4 Booster Hydraulic Power Arrangement as a guide. The resulting (see table 3.3.5) line run length were compiled. (It is noted that information from a previous weight analysis study was used were possible.)

The Auxiliary pump is shown in 3.3.3.

3.3.1 BOOSTER CONFIGURATION 20A HYDRAULIC SYSTEM BLOCK DIAGRAM





3.3.2 HYDRAULIC SYSTEM LINE SCHEMATIC (SYS NO 3)

3.3.3

PMP2V-6B AUXILIARY MOTOR DRIVEN HYDRAULIC PUMP

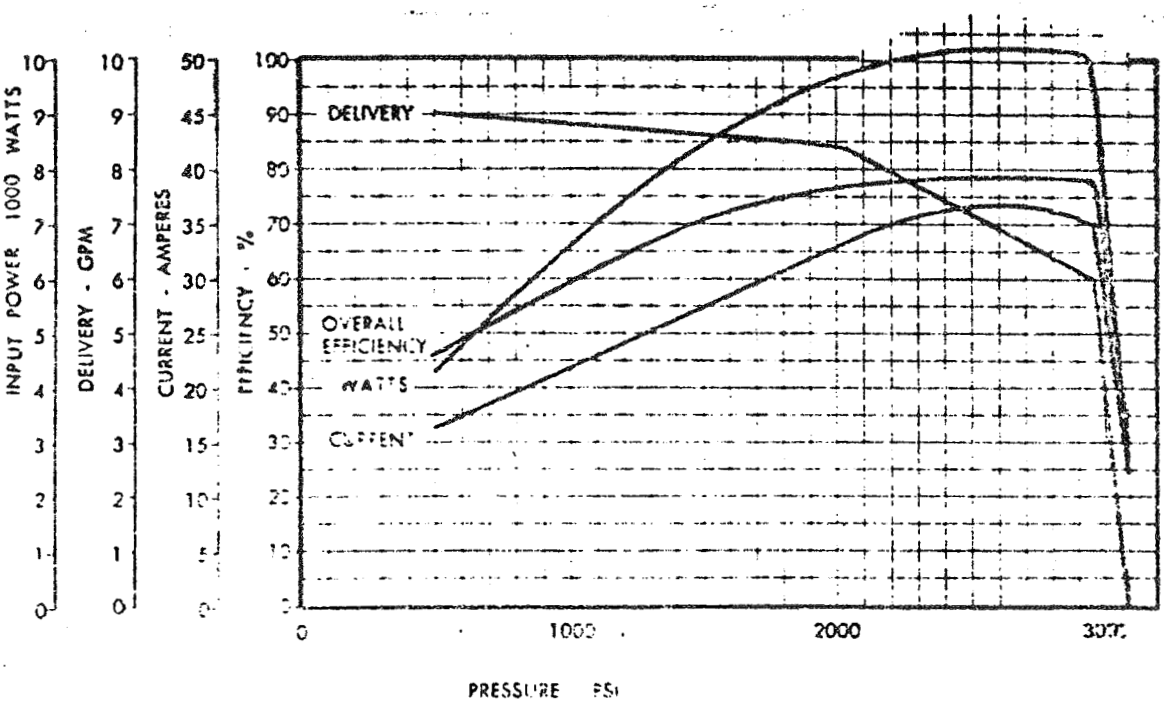
SPECIFICATIONS:

MOTOR:
TASK CORPORATION, 115/200 VAC, 3 PHASE
400 CPS, 12 HP.

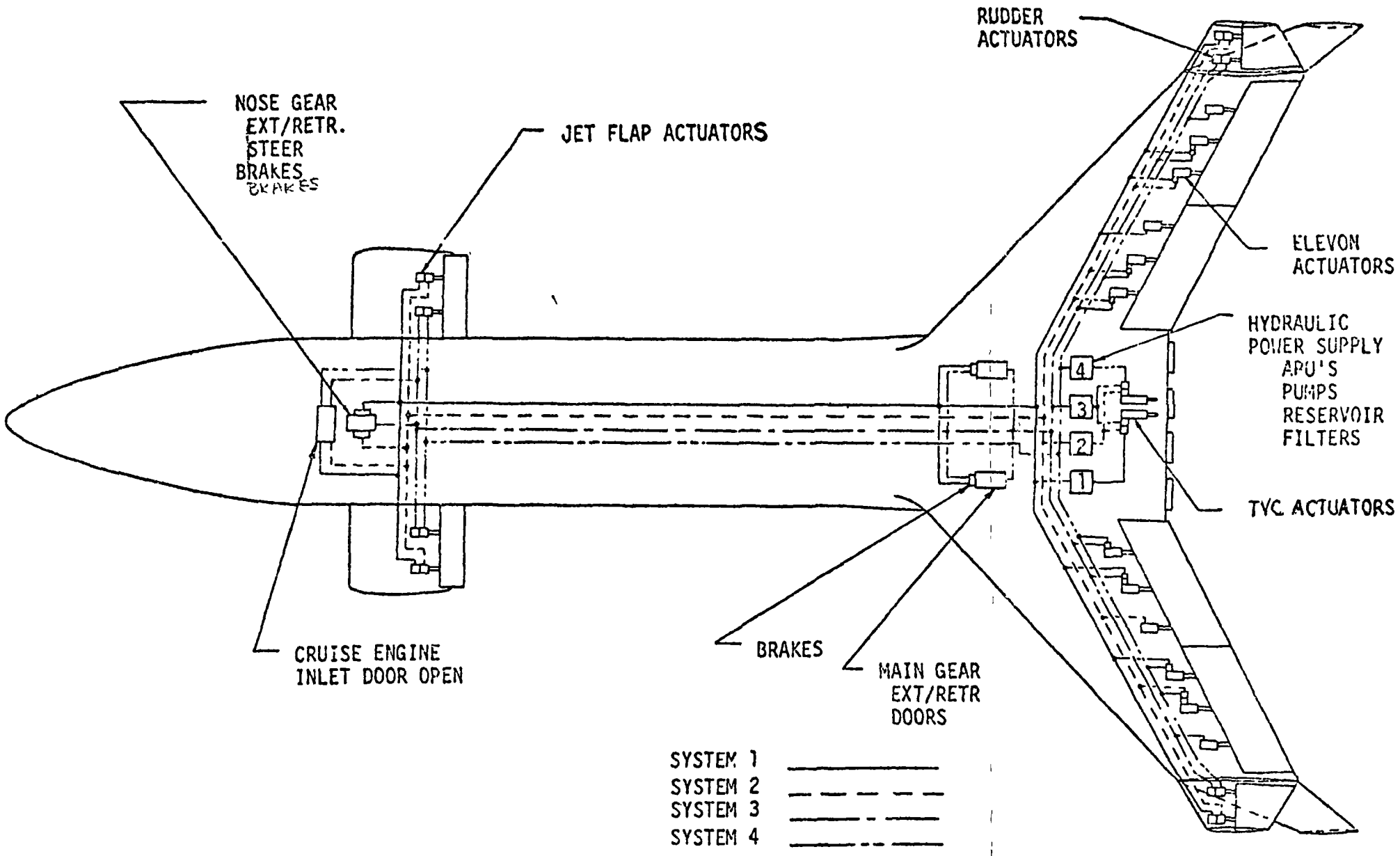
PUMP:
ABEX CORPORATION APDV-33

MOTOR-PUMP:

RATED CURRENT	37.5 AMPS
RATED DELIVERY	8.0 GPM @ 2200 PSI
RATED OUTLET PRESSURE	3000 PSI
MINIMUM INLET PRESSURE	2.0 PSI
TEMPERATURE RANGE	-65° - +165°F.
WEIGHT (DRY) MAXIMUM	33.1 LBS
FLUID	MIL-H-5606



3.3.4 BOOSTER HYDRAULIC POWER ARRANGEMENT



3.3.5 Table of Line Run Lengths

Line Run	Length (ft)
1	3.0
1a	3.0
2	36.2
3	15.5
4	18.5
5	2.0
5a	2.0
6	29.0
7	5.0
8	4.0
8a	4.0
8b	5.0
9	49.0
10	24.2
11	48.6
12	32.7
13	32.7
14	198.0
15	30.9
16	30.9
17	255.2
18	3.0

3.4 Line Sizing and Weight Analysis - This section of the weight analysis determines the line sizes based on a limiting line velocity of 20 ft/sec. The maximum flow rate for each line was determined by the following means:

a) Using Table 3.4.2 Actuator Flow Rates

b) Using Figure 1, 3.4.3 Booster Hydraulic Power Profile.

c) Using the accumulated line run flow indicated by 3.3.2 Hydraulic System Line Schematic.

d) Line flows from the previous report which had not changed which includes the following lines:

Line No.	Flow Rate (gpm)
8	30.0
8a	3.0
8b	33.0
12	42.0
13	30.0
14	32.0
16	16.0
17	5.0
18	3.0
3	5.0

Determination of conversion factor

HP X C_1 = qpm where C_1 is the conversion factor which changes HP to gpm.

$$\frac{(X\ HP) \times \left(33{,}000\ \frac{ft.lb}{HP.min}\right) \times \left(12\ \frac{in}{ft}\right)}{3000\ \frac{lb}{in^2}\quad 231\ \frac{in^3}{gal}} =$$

$$(X\ HP)\ (1.75^{-1}) \left(\frac{gal}{min.HP}\right) = gpm$$

Line Flow Rate

Line 1

From 3.4.3 550 HP x $(1.75)^{-1}$ = 315 gpm

(This is less than the 363 gpm that results by using the true pressure of 2600 psi. The 315 gpm value was used since the line size determined by the 363 gpm value was too conservative based on pressure loss per foot.)

Line 1a

The flow rate of 7 gpm was increased to 28 gpm since this line services all 4 pumps.

Line 2

The flow rate in line 2 is (using 3.4.2) [(27.5 gpm x 16 actr) + (1.965 gpm x 24 ACT) + (7.81 gpm x 8 ACT)] $\frac{1}{3 \text{ SYSTEMS}}$ = 184 gpm/system + δ engine control supply = 187 gpm

Line 3

5 gpm from previous report.

Line 4

Since there are 2 TVC actuators on each line 4, the max expected flow (using 3.4.2 data) is (2) (27.5 gpm) - 55 gpm.

Line 5

The return line is sized for full system flow of (550 HP/175) = 315 gpm.

Line 5a

Since flow is small in this line, the line was sized to minimum size compatible with good practice; .375 O.D.

Line 6

Since this line should be sized for full system flow less TVC leakage, flow in line 6 = 550×175^{-1} - 47.2 gpm (TVC leakage)

= 315 - 47.2 = 267.8 gpm

Line 7

This line should be sized for full system flow of 550 HP x 1.75^{-1} = 315 gpm

Line 9

The max flow occurs during landing with rudder and evelon rates 24 and 20 deg/sec respectively.

Flow = (2 elevon actr) (4.53) (20 deg/sec) + (½ actr) x [(24)(3.63)] = (181.2 + 43.56) gpm = 225 gpm

Line 10

Line has a max of one actuator and on leakage point = 90.7 (from 3.4.2) gpm + 3.4 = 94.1 gpm

Line 11

Line has one half actr flow to each line. Flow = (½)(3.63)(24 deg/sec) = 43.6 gpm

Line 15

Line size from previous analysis was retained.

Line Size Determination

The line sizes were determined from tabulation of line sizes vs. gpm of paragraph 3.2.3.

Line and Fluid Weights per Unit determination

Weight per unit ft. of tubing and fluid is found in tabulation 3.2.1 for titanium and 3.2.2 for aluminum.

3.4.1 Line Sizing

Line No	Θ	Flow GPM	Size In	Length Ft	No. of Lines		Total Length	Wt/Ft. lb.	Matl.Wt. lb.	Fluid lb/ft	Fluid Wt. lb
1	P	315	2.750	3.0	1	T	3.0	2.375	7.125	1.773	5.319
1a	D	28	.875	3.0	1	T	3.0	.260	.78	.1768	.530
2	P	183	2.125	36.2	1	T	36.2	1.425	51.585	1.057	38.260
	R	183	2.125	36.2	1	T	36.2	1.425	51.585	1.057	38.260
3	P	7	.4375	15.5	3	T	46.5	.0656	3.050	.0443	2.060
	R	7	.4375	15.5	3	T	46.5	.0656	3.050	.0443	2.060
4	P	55	1.250	18.5	8	T	148.0	.508	75.184	.3636	53.813
	R	55	1.250	18.5	8	T	148.0	.508	75.184	.3636	53.813
4a	P	28	.875	18.5	4	T	148.0	.260	38.480	.1768	26.166
	R	28	.875	18.5	4	T	148.0	.260	38.480	.1768	26.166
5	R	315	2.750	2.0	1	T	2.0	2.375	4.750	1.773	3.546
5a	P	-0-	.375	2.0	1	T	2.0	.0515	.1030	.0317	.063
6	P	268	2.500	29.0	1	T	29.0	1.984	57.7	1.462	42.4
	R	268	2.500	29.0	1	A	29.0	1.220	35.4	1.5228	44.2
7	R	315	2.750	5.0	1	T	5.0	2.375	11.875	1.773	8.865
8	P	30	.875	4.0	1	T	4.0	.260	1.040	.1768	7.072
8a	R	3	.375	4.0	1	T	4.0	.0515	.206	.0317	.127
8B	R	33	.875	5.0	1	T	5.0	.260	1.300	.1768	.884
9	P	225	2.375	49.0	2	T	98.0	1.785	174.93	1.3201	129.360
	R	225	2.375	49.0	2	A	98.0	1.080	106.90	1.3788	135.122
10	P	94	1.500	24.2	4	T	96.8	.735	71.148	.5231	50.636
	R	94	1.500	24.2	4	A	96.8	.427	41.700	.5508	53.174
11	P	44	1.000	48.6	2	T	97.2	.342	33.242	.230	22.356
	R	44	1.000	48.6	2	A	97.2	.1908	18.546	.244	23.717
12	P	42	1.000	32.7	1	T	32.1	.342	10.978	.230	7.383
	R	42	1.000	32.7	1	A	32.1	.1908	6.125	.244	7.832
13	P	30	.875	32.7	1	T	32.7	.260	8.502	.1768	5.781
	R	30	.875	32.7	1	A	32.7	.153	5.003	.1861	6.085
14	P	32	.875	198.0	1	T	198.0	.260	51.480	.1768	35.006
	R	32	.875	198.0	1	A	198.0	.153	30.294	.1861	36.848
15	P	10	.500	30.9	2	T	61.8	.0820	5.068	.0580	3.584
	R	10	.500	30.9	2	A	61.8	.0486	3.004	.0608	3.757
16	P	16	.625	30.9	2	T	61.8	.140	8.652	.0889	5.494
	R	16	.625	30.9	2	A	61.8	.0760	4.697	.0950	5.871
17	P	5	.4375	255.7	1	T	255.7	.0656	16.774	.0443	11.328
	R	5	.4375	255.7	1	A	255.7	.0378	9.665	.0464	11.864
*18	P	3	.375	3.0	1	T	3.0	.0515	.145	.0317	.095
	R	3	.375	3.0	1	A	3.0	.0343	.103	.0331	.0993
									1063.6 LB		909.762
									-.248		-.194
									1063.4 LB		909.568 LB

T = TITANIUM
A = ALUMINUM

P = PRESSURE
R = RETURN
D = DRAIN

SYSTEMS #1,24 LESS 18 SYSTEM #3

* NOT REQUIRED FOR SYSTEM #3

Correction Factor

Total line weight including line 18 is 1044.6 lbs

(+ correction factor for change in line 6 from 2.250 to 2.50 in OD) + 19.2

1063.8

Percent error = $\frac{19.2}{1063.8}$ x 100 = 1.8%

Total hydraulic fluid weight including line 18 is:

892.762

+17.0 (Correction wt for increase in line 6 size)

909.762 Total corrected wt.

Percent error = (17/909.762) x 100 = 1.54%

System tubing wt used throughout this report is 1044.56 lbs per system (there are four systems).

Wt. of hydraulic fluid used throughout this report is 892.762 lbs per system (there are four systems).

The accuracy of the lines and fluid is well within the capability of determining the line run lengths.

3.4.2 ACTUATOR FLOW RATES

ACTR	FLOW FACTOR	TRANSITION RATE	TRANSITION FLOW	NO. OF ACTR	TOTAL FLOW	LANDING RATE	LANDING FLOW	TOTAL FLOW	HALF ** FLOW
		(θ̇ °/sec)	(GPM)	4	259	(θ̇)		(362)	181.0
ELEVON	4.53θ̇	14	63.5	3*	—	20	90.7	272	189 Ⓦ LEAKAGE
								Q_L = 10	Ⓞ
RUDDER	3.63θ̇	20	72.6	1	72.6	24	87.0	72.6	36.3
								Q_L = 2.2	37 Ⓦ LEAKAGE
								.1	⊖
JET FLAP	0.74θ̇	0	—			10	7.4	7.4	217.3
							TOTAL	364.3	226 Ⓦ LEAKAGE

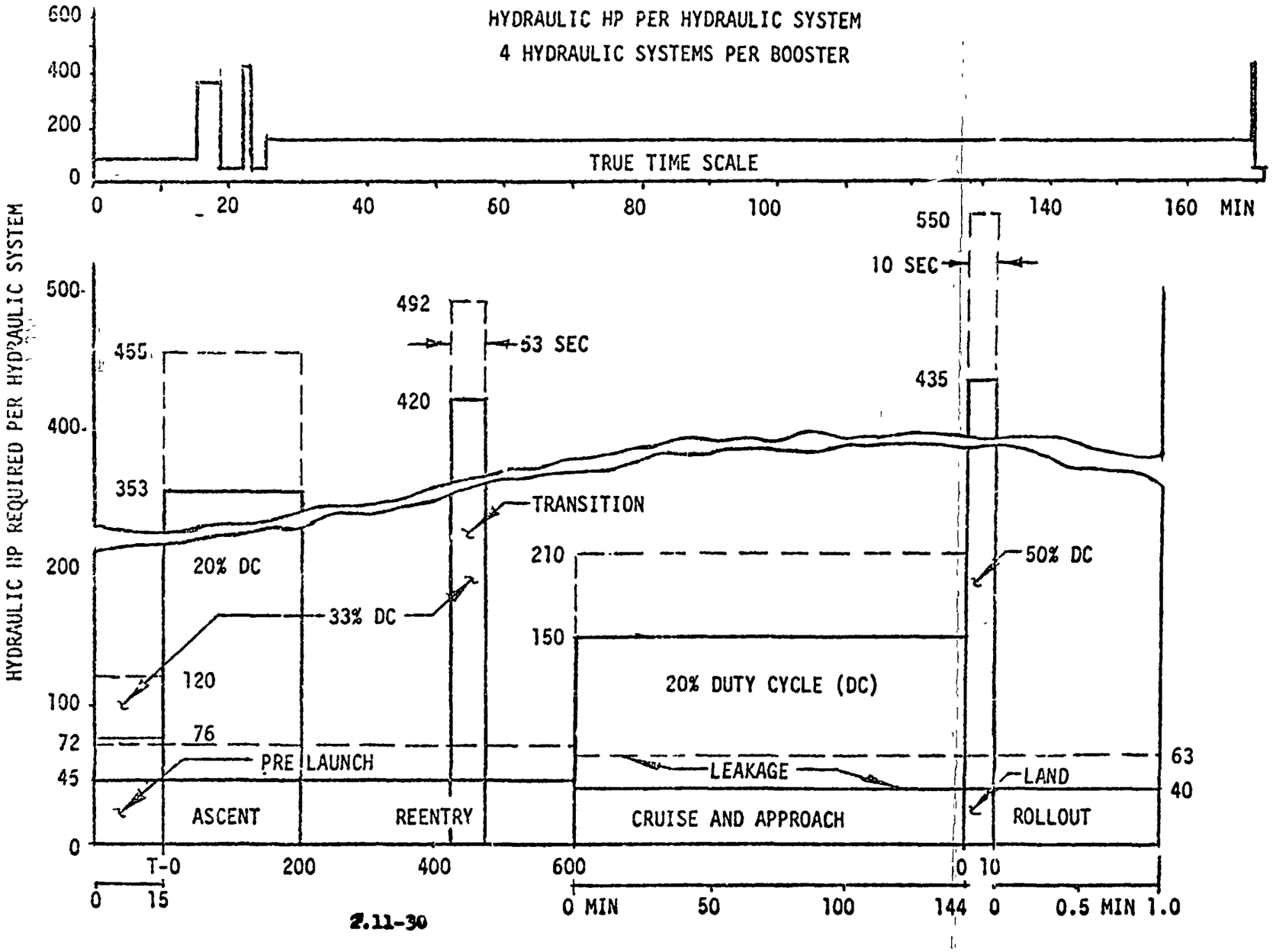
	FLOW FACTOR	θ̇ ASCENT RATE	(GPM) ASCENT FLOW	NO. OF ACTR	TOTAL FLOW	TOTAL ACTR LEAKAGE	TOTAL FLOW	
TVC	3.94θ̇	7	27.5	4	110	"		
TVC	3.94θ̇	2	7.87	2	15.8			
					126.0	11.8	138	NORMAL
				Δ	168.0	15.7	184	FO
				▽	126.0	23.6	150	FO/FS

Ⓞ TVC LEAKAGE = 1.965 GPM/ACTR × 6 ACTR = 11.8 GPM : FO ; 8/6 11.8 = 15.7 GPM ; FO/FS ; 11.8 × 2 = 23.6 GPM
Ⓦ ELEVON LEAKAGE = 3.4 GPM/ACTR × 2 ACTR = 6.8 GPM : × 3 ACTR = 10.2 GPM
⊖ RUDDER " " 2.18 " " " 1/2 " " 1.09 " : × 1 ACTR = 2.18 GPM

Δ SINCE 8 ACTR ARE SUPPLIED BY EACH APU DURING FO, Q = 126 × 8/6 = 168 GPM
▽ " 12 " " " " " " " " FO/FS, Q = 126 × 12/6 × 1/2 = 126 GPM
(THE RATE FOR FS IS 1/2 RATE FOR FO)

* MAX ACTR/HYD SYS (2 per 1/2 SYSTEM) DURING THE LANDING PHASE.
** FLOW TO LEFT OR RIGHT WING.

3.4.3 BOOSTER HYDRAULIC POWER PROFILE



3.5 Actuator Weight and Volume Summary - The total control system actuator weight and volume is shown in paragraph 3.5.1. Table 3.5.2 lists the was and is conditions for these data. Table 3.5.3 is a summary of the current control systems parameters.

3.5.1 Actuator Weights and Volumes

Item	No. Req'd	Weight Item (lbs)	Volume Item (in^3)	Weight (lbs)	Volume (in^3)
Elevon Actuators	12	567	1050	6804	13,800
Rudder Actuators	4	390	400	1560	1600
Jet Flap Actuators	4	110	82	440	328
TVC Actuators	24	187	191	4488	4584
			Totals	13,292	20,312

Actuator Weight

Moog Chart Weight = $0.6145\ (1550)^{0.91}$

(Reference: Moog Technical Bulletin 119)

Using the above equation for determining the cylinder weights, using a 1.75 weight increase factor for each tandem actuator and adding valve component, manifold and fitting weights, the valves of servo actuator weights shown in Table 3.5.2 and 3.5.3 were determined. From these tables the actuator weights and volumes summary was made (3.5.1 Actuator Weights and Volumes).

TABLE 3.5.2
BOOSTER CONFIGURATION 20A
FLIGHT CONTROL ACTUATOR CHANGES - MIDTERM TO FINAL

	TYPE & NUMBER	SURFACE HINGE MOMENT FT - LB	SURFACE AXIAL LOAD LB	MOMENT ARM IN	STROKE IN	PISTON AREA IN^2	DISPLACEMENT IN^3	WEIGHT LB
OUTBOARD ELEVON								
WAS	TANDEM, 1 PER SURFACE, 2 TOTAL	202,000 BALANCED 25%	269,000 BALANCED 25%	9.0	13.3	44.9	596	363
IS	SINGLE, 3 PER SURFACE, 6 TOTAL	500,000	387,000	15.5	18.0	64.5	1150	567
INBOARD ELEVON								
WAS	TANDEM, 1 PER SURFACE, 2 TOTAL	288,000 BALANCED 25%	288,000 BALANCED 25%	12.0	17.7	48.0	850	480
IS	SINGLE, 3 PER SURFACE, 6 TOTAL	500,000	387,000	15.5	18.0	64.5	1150	567
RUDDER								
WAS	TANDEM, 1 PER SURFACE, 2 TOTAL	180,000 BALANCED 25%	205,500 BALANCED 25%	7.0	7.0	51.4	360	252
IS	TANDEM, 2 PER SURFACE, 4 TOTAL	200,000	300,000	8.0	8.0	50.0	400	330
JET FLAP								
WAS	TANDEM, 1 PER SURFACE, 2 TOTAL	181,000	TBD	TBD	TBD	TBD	513	295
IS	TANDEM, 2 PER SURFACE, 4 TOTAL	41,000	49,000	10.0	10.0	8.2	82	110
TVC								
WAS	SINGLE, 2 PER ENGINE, 24 TOTAL	196,000	98,000	24.0	5.9	32.7	191	180
IS	SAME	208,000	69,305*	30.1*	10.9*	29.8*	325*	187

*DATA SHOWN ARE FOR THE ROCKETDYNE ENGINE.

BASELINE FLIGHT CONTPOL ACTUATOR DATA
MODEL 20A BOOSTER

TABLE 35.3

	OUTBOARD ELEVON	INBOARD ELEVON	RUDDER	JET FLAP	TVC
TYPE & NUMBER	SINGLE, 3/SURFACE 6 TOTAL	SINGLE, 3/SURFACE 6 TOTAL	TANDEM, 2/SURFACE 4 TOTAL	TANDEM, 2/SURFACE 4 TOTAL	SINGLE 2/ENGINE 24 TOTAL
HINGE MOMENT, FT-LB PER SURFACE	500,000	500,000	200,000	41,000	208,000
TOTAL AXIAL LOAD, LB PER SURFACE	387,000	387,000	300,000	49,000	69,300
MOMENT ARM, IN	15.5	15.5	8.0	10.0	24.0
STROKE, IN.	18.0	18.0	8.0	10.0	5.9
PISTON AREA IN PER CYLINDER	64.5	64.5	50.0	8.2	32.7
DISPLACEMENT, IN^3 PER CHAMBER	1150	1150	400	82	191
WEIGHT, LB PER ACTUATOR	567	567	390	110	187

3.6 Actuator Line Run Weight & Volume Summary - This summary was made for the purpose of allocating specific line runs to subsystems such as the Elevon actuator subsystem, TVC actuator subsystem, etc.

WEIGHTS ARE PER SYSTEM (THERE ARE FOUR SYSTEMS)

LINES	NO		LINE WT	TOTAL	FLUID WT	TOTAL
TVC	4	T	150.37		107.63	
	4a	T	76.96	227.33	52.33	159.96
ELEVON	10	T	71.15	112.85	50.64	103.81
	10	A	41.70		53.17	
RUDDER	11	T	33.24	51.79	22.36	46.08
	11	A	18.55		23.72	
JET FLAPS	15	T	5.07	8.07	3.58	7.34
	15	A	3.00		3.76	
BRAKES	13	T	8.50	13.50	5.78	11.87
	13	A	5.00		6.09	
STEERING	18	T	.15	.25	.10	.20
	18	A	.10		.10	
LANDING GEAR	12	T	10.98	43.55	7.38	38.40
	12	A	6.13		7.83	
	17	T	16.77		11.33	
	17	A	9.67		11.86	
AFES	16	T	8.65	13.35	5.49	11.36
	16	A	4.70		5.87	
ENGINE	3	T	3.05	6.10	2.06	4.12
	3	T	3.05		2.06	
		TOTAL PER SYSTEM		476.79 LB		382.14 LB

3.7. Power System Line and Fluid Weight Summary

Determine Power System Lines & Fitting wt.

	Lines and Fittings	Hydraulic Fluid
	lbs	lbs
Total Weights	1044.35	892.57
Actr LEF "	476.79	382.14
P.S. "	567.56	510.43
No. of Systems	4	4
Booster Weights	2270.24	2041.72

3.8 Reservoir Sizing Study & Summary

Consider:

1. Actr ΔV
2. Allowance for accumulator
3. Thermal compression
4. 5% of system vol. for fill-refill
5. Empty vol. for fluid expansion 100°F to 275°F
6. Compression of fluid to 3000 psi and 1500 psi

Factors:

Bulk modulus

Thermal coefficient of volumetric expansion

Consider system No. 3 (largest system)

1. Actr $\Delta V = 23\ in^3 + 411\ in^3 = 434\ in^3$

   $\boxed{\Delta V = 434\ in^3}$ (unchanged from previous study)

2. Accumulator Volume = 885 in^3/sys was)

   HP landing load = 550

   flow landing load = $550 \times 175^{-1} \frac{3000}{2606} = 362$ gal/min

   362/60 = 6.04 gal/sec or 3.02 gal/½ sec

   $3.02 \times 231 = 700\ in^3$

   $\boxed{\text{Accumulator Volume} = 700\ in^3}$

3. Thermal Compression

   100°F to 0°F = ΔT = 100°F

Lines & Fittings	29752.0
Actuator	20312.0
Utility Actr Vol	2892.0
Pump Vol	52.0
Distribution Manifold	2880.0
Reservoir (Approximate)	9000.0
	64880.0

$$V = (\Delta t)(\alpha_t)(\text{Volume})$$

$$= (100\ ^\circ F)(4.3 \times 10^{-4} \frac{in^3}{^\circ F\ in^3})(64{,}888\ in^3)$$

$$= 2.79 \times 10^3 = 2790\ in^3$$

$$\boxed{V_T = 2790\ in^3}$$

6. Compression to 3000

Based on 3000/4000 psi system study

Assume return line vol = 0.511 x (total pluming of 29,752 in^3)

Vol (Return line) = 0.511 x 29.752 = 15,200 in^3

Vol under compression 64,888 - (15,200 + 9,000)

Vol under compression = 40,688 in^3

$$\Delta V \text{ comp} = V \frac{\Delta P}{\beta} = 40{,}688 \times \frac{3000}{164{,}800}$$

$\boxed{V \text{ comp} = 745 \text{ in}^3}$

4. 5% System Vol

$\Delta V = 64{,}888 \times .05 = 3.245 \times 10^3 = 3.245 \text{ in}^3$

$\boxed{\Delta V \ 5\% = 3{,}245 \text{ in}^3}$

5. Additional Empty Volume for expansion to 275°F

(4.) $\Delta V5\%$ = 3,245

(6) ΔV comp = 745

(3.) ΔV_T = 2,790

(1) ΔV act = 434
(2.) ΔV accum = 700

7,914 in^3 = vol of fluid in Reservoir @ 100°F

52 in^3 (5% 1034 in^3) correction factor

Σ 1-4½6 = $\boxed{7{,}966 \text{ in}^3}$

Additional empty vol for expansion to 275

Fluid Vol. @ 100°F = (64,888 - 9000 + 7,966) in^3 = 63,854 in^3

Fluid Vol @ 100°F = 63,854 in^3

$\Delta V = (\Delta t)(\alpha_T)(V_{tol}) = (175°F)(4.3 \times 10^{-4})(63{,}854)$

$\boxed{\Delta V = 4810 \text{ in}^3}$

(Σ 1-4½6) (5)

Reservoir fluid vol. @ 175°F = 7,966 + 4810 in^3 = 12,776 in^3

Vol res = 12,776 in^3 = 55.3 gal

Reservoir Sizing (continued)

Approx Res wt = (DC 10 Res wt) $\frac{12,776}{\text{DC 10 Res Vol}}$

$= 62.7 \quad \frac{12,776}{2,820} = \underline{\underline{284 \text{ lb}}}$

Reservoir wt = 284 lb

Reservoir Sizing Summary

Vol res = 12,776 in^3 (fill to 7,966 in^3 @ 100°F)

Vol res = 55.3 gal

Hydraulic System Fluid Vol @ 100°F - 69,075 in^3

Res wt = 284 lbs

Fluid Weight = 1,915.62 lbs (Total System)

Reservoir Fluid wt = 238.98 lb (7966 in^3)

3.9 System Weight Breakdown Analysis

Total System wt = 28,474 lbs

Brakes - 490 lbs

Steering - 101 lbs

Landing Gear - 405 lbs

(Sys) 4 | 27,478 = (6,869.5 lbs Basic Hyd Sys Weight)

Hydraulic System Weights

System #1 = 6869.5 lbs Base Wt
50.5 lbs Steering Wt
245.0 lbs Brakes wt
Total = 7165.0 lbs Sys. No. 1 Weight

System #2 6869.5 lbs Base wt
50.5 lbs Steering wt
Total = 6920.0 lbs Sys. No. 2 Weight

System #3 6869.5 lbs Base wt
405.0 lbs Landing gear wt
245.0 lbs Brakes wt
Total = 7519.5 lbs Sys. No. 3 Weight

System #4 TOTAL = 6869.5 lb Sys. No. 4 Weight

Weight Summary

System No. 1 Weight	7165 lbs
System No. 2 Weight	6920 lbs
System No. 3 Weight	7519.5 lbs
System No. 4 Weight	6869.5 lbs

12. SURFACE CONTROLS 11320

	WEIGHT (LB)	PAGE NO.
ELEVONS	(8617)	2.12-3
ACTUATORS	6804	2.11-31
LINES, FITTINGS & INSTALLATION	451	2.12-3
SUPPORTS & INSTALLATION (ACTUATORS)	1293	2.12-3
CONTROL WIRING	69	2.12-4
RUDDERS	(2124)	2.12-3
ACTUATORS	1560	2.11-31
LINES, FITTINGS & INSTALLATION	207	2.12-3
SUPPORTS & INSTALLATION (ACTUATORS)	296	2.12-3
CONTROL WIRING	61	2.12-4
CANARD FLAPS	(579)	2.12-3
ACTUATORS	440	2.11-31
LINES, FITTINGS & INSTALLATION	32	2.12-3
SUPPORTS & INSTALLATION (ACTUATORS)	84	2.12-3
CONTROL WIRING	23	2.12-4

12. SURFACE CONTROLS

11320

COCKPIT CONTROLS
FLIGHT CONTROL SY
SYSTEM ACTUATION

	CONTROLS	POWER XMISSION	ACTUATOR	FEEL SY	SUPTS INSTALL.	(SEE AVIONICS)
	(153)	(690)	(8804)	(—)	(1673)	11320
ELEVON	69	451	6804	—	1293	
CANARD FLAP	23	32	440	—	84	
RUDDER	61	207	1560	—	296	
T.E FLAP						
SPEED BRAKE						

ACTUATORS AND PLUMBING

DUE TO THE CLOSE INTERRELATIONSHIP BETWEEN THE SURFACE CONTROL ACTUATORS PLUS THEIR ASSOCIATED PLUMBING AND THE HYDRAULIC SYSTEM, THE DERIVATION OF THESE WEIGHTS ARE IN SECTION 2.11 HYDRAULICS SYSTEM.

SUPPORTS AND INSTALLATION

A 19% FACTOR WAS APPLIED TO THE ACTUATOR WEIGHTS (REF: DC-8F 19%)

ELEVONS WT. = .19 X 8617 = 1293 LB

RUDDERS WT = .19 X 1560 = 296 LB

CANARD FLAPS WT = .19 X 440 = 84 LB

SURFACE CONTROLS

CONTROL WIRING

ASSUME 4 LB. PER 1000' OF WIRING, CONNECTORS AND INSTALLATION. ASSUME A 1.7 ROUTING FACTOR FOR WIRING IN WING AND CANARD.

14 SIGNALS PER CHANNEL
4 CHANNELS PER SECONDARY ACTUATOR
1 SECONDARY ACTUATOR PER SURFACE FOR ELEVONS & RUDDER
2 SECONDARY ACTUATORS PER SURFACE FOR CANARD FLAP
4 ELEVONS, 2 RUDDERS, AND 2 CANARD FLAPS

ELEVONS - $WT = \frac{4\#}{1000'} \times 14 \times 4 \times 1 \times 4 \times 45'_{(AVG)} \times 1.7 = \underline{69\ LB}$

RUDDERS - $WT = \frac{4\#}{1000'} \times 14 \times 4 \times 1 \times 2 \times 80' \times 1.7 = \underline{61\ LB}$

CANARD FLAP - $WT = \frac{4\#}{1000'} \times 14 \times 4 \times 2 \times 2 \times 15' \times 1.7 = \underline{23\ LB}$

2.13 AVIONICS ---------- 4941

		Page No.
Guidance and Navigation	[278]	2.13-4
Inertial Measurement Unit	140	
Circuitry	24	
Navigation Base	80	
Local Mounting Structure	10	
Equipment Bay Structure	24	
Flight Control System	[1159]	2.13-5
Thruster Electronics	70	
Actuator Electronics	184	
TVC Actuator Electronics	342	
Rate Gyro Package	16	
Total Temp & Press Sensor	10	
Accelerometer	6	
Static Press Sensor	10	
Pitch Angle of Attack	4	
Sideslip Sensors	4	
Normalized Pressure Sensors	4	
Actuator Assem-Pilot Static Angle of Attack Sensors	215	
Circuitry	175	
Local Mounting Structure	28	
Equipment Bay Structure	91	
Data Management	[1217]	2.13-9
Central Computer	340	
System Control Unit	7	
Mass Memory	32	
Area DIU's	162	
Crew Station DIU's	114	
IMU DIU's	20	
Data Bus	36	
Maintenance Recorder	100	
Input/Output Control Unit	24	
Circuitry	242	
Local Mounting Structure	33	
Equipment Bay Structure	107	

2.13 Avionics - Continued

		Page No.
Communications & Nav	[853]	2.13-10
Audio Control Center	36	
UHF Transceiver	36	
UHF Antenna	39	
UHF Ant Window & Instl	46	
DME Receiver	90	
DME Antenna	4	
DME Ant Window & Instl	50	
Glideslope Receiver	12	
Glideslope Antenna	6	
GS Ant Window & Instl	33	
VOR/LOC Receiver	60	
VOR/LOC Antenna	32	
VOR/LOC Ant Wind & Instl	66	
Radio Altimeter	63	
Radio Altimeter Antenna	6	
Radio Alt Ant Window & Instl	71	
ATC Transponder	20	
ATC Antenna	1	
ATC Ant Window & Instl	13	
Circuitry	95	
Local Mounting Structure	17	
Equipment Bay Structure	57	
Displays & Controls	[808]	2.13-16
Center Front Panel	166	2.13-13
Command Pilot Front Panel	126	2.13-13
Pilot Front Panel	123	2.13-14
Command Pilot Outb'd Panel	19	2.13-14
Pilot Outboard Panel	25	2.13-14
Center Console Panel	63	2.13-15
Floor Area	50	2.13-15
Overhead Panel	40	2.13-15
Circuitry	162	2.13-16
Window Frame Mount	6	2.13-15
Local Mounting Structure	27	2.13-16
Roundoff	1	
Contingency	[626]	2.13-16

2.13. AVIONICS

GENERAL - The Avionics System is a fully integrated electronics system which performs the matrix of system functions outlined in Part II Figure 2.13-1.

Basic system design criteria is FO, FO, FS with the exception of Communications and some Navigation equipment (an official level I deviation has been granted for these items). There is essentially total commonality of Orbiter and Booster system components. The number of units and type of equipments vary slightly due to differences in mission requirements (see Part II, Sect. 2.13 for Orbiter Avionics).

Following NASA Technical Directive No. 2493 for Avionics System Reporting Format, an additional line item system breakdown is supplied on pages 2.13-20 and 2.13-21.

GROUP WEIGHT STATEMENT

	UNITS	CIRCUITRY	COOLING	ANTENNAS	INSTALL.		
13. AVIONICS	(2555)	(698)	(N/A)	(88)	(974)		4941
① GUID/NAV	140	24			114	278	
② FLIGHT CONTROL	650	175			334	1159	
③ DATA MANAGEMENT	835	242			140	1217	
④ COMMUNICATE	317	95		88	353	853	
CONFIG. SEQ, INSTRUMENTATION	SEE DATA MANAGEMENT						
⑤ DISPLAYS	613	162			33	808	
⑥ CONTINGENCY						626	

WEIGHT SUBSTANTIATION

ITEM	REF. NO. PG 2.13.-13	UNIT WEIGHT	QTY	TOTAL WEIGHT
① GUIDANCE AND NAVIGATION	1.			
INERTIAL MEASUREMENT UNIT	2.	35	4	140
SUBTOTAL EQUIPMENT				(140)
NAVIGATION BASE	5.			80
SUBTOTAL MOUNTED EQUIP.				(220)
CIRCUITRY WT = $.039(140)^{1.298}$				24
LOCAL MTG. STR. WT = $.412(220)^{.65}$				10
EQ. BAY STR. WT = $1.35(220)^{.65}$				24
TOTAL GUIDANCE AND NAVIGATION				278 LB

WEIGHT SUBSTANTIATION

ITEM	REF. NO. PG 2.13-13	UNIT WEIGHT	QTY	TOTAL WEIGHT
②FLIGHT CONTROL SYSTEM	6.			
THRUSTER ELECTRONICS	7.	7.	10	70.
ACTUATOR ELECTRONICS - AFT	8.	28.5	4	114.
ACTUATOR ELECT - MIDSHIPS	8.	17.5	4	70.
TVC ACTUATOR ELECT.	8	28.5	12	342
RATE GYRO PACKAGE	9.	4.	4	16.
TOTAL TEMP & PRESS SENSOR	10.	2.5	4	10.
ACCELEROMETER	11.	1.5	4	6.
STATIC PRESS SENSOR	12.	2 5	4	10
PITCH ANGLE OF ATTACK SENSORS		1.0	4	4.
SIDE SLIP SENSORS		1.0	4	4.
NORMALIZED PRESS. SENSORS		1.0	4	4
SUBTOTAL EQUIPMENT				(650.)**
ACTUATOR ASSEM - PITOT STATIC / ANGLE OF ATTACK SENSORS	*			215
CIRCUITRY WT = $.039(650)^{1.298}$ =				175
LOCAL MTG. STR. WT = $.412(650)^{.65}$ =				28
EQUIP BAY STR. WT = $1.35(650)^{.65}$ =				91
TOTAL FLIGHT CONTROL SYSTEM				1159 LB

* CALCULATION SHOWN ON FOLLOWING PAGES

** THE TOTAL SHOWN UNDER "UNITS" FOR FLIGHT CONTROL IN THE GROUP WEIGHT STATEMENT (TABLE 5-2 OF PART I) IS 885 LB. THIS TOTAL IS OBTAINED BY COMBINING THE 650 LB EQUIPMENT SUBTOTAL ABOVE WITH THE 215 LB ACTUATOR ASSEMBLY.

ACTUATOR ASSEM – PITOT STATIC / ANGLE OF ATTACK SENSORS

SCREW JACK	29.0
PRESSURE TUBE	14.2
SUPPORT TUBE	9 9
RAIL GUIDE ASSEM	7.1
DOOR ASSEM.	5.0
FWD HOUSING ASSEM	8.6
BELLOWS ASSEM	3.9
BRACKETS & FITTINGS	19.8
MISC & CONTINGENCY	10.0
WEIGHT/EACH	107.5
WEIGHT / BOOSTER	215.0#

SCREW JACK

SCREW LENGTH = 62.00 INCHES
O.D = 2.25 "
WALL = 0.125 "

WT = .125 (3.14)(2.25 - .125)(62)(.283) =	14.6	
ELECTRIC MOTOR	6.0	
" " GEAR	0.3	
GEAR CAGE & BEARINGS	1.8	
THRUST BEARINGS (2)	0.6	29.0#
BRAKE	1.7	
LIMIT SWITCH	0.2	
HOUSING (ALUM)	2 6	
MISC & ATT PARTS	1.2	

PRESSURE TUBE (ALUM)

LENGTH = 60"
t_{wall} = .150
I.D = 5.0"

WT = 3.14 (5.15)(60)(.150)(0.100) = 14.2#

SUPPORT TUBE (ALUM)

LENGTH = 72"
t = .090
O.D = 5.0"

WT = 3.14 (4.91)(72)(.090)(0.100) = 9.9#

RAIL GUIDE ASSEM.

ASSUME $\frac{1}{2}$ PRESS TUBE WT FOR BOTH RAILS = 7.1#

DOOR ASSEM.

DOOR & JAMB	1.20
BRACE LINK (ALUM)	0.30
LINK	0.35
PINS (4)	0.60
LATCHES (2)	0.60
SPRINGS	0.53
RETAINERS	0.02
TUBE ADAPTER FTG	0.90
BRACKET	0.30
LIMIT SWITCHES	0.20

= 5.0#

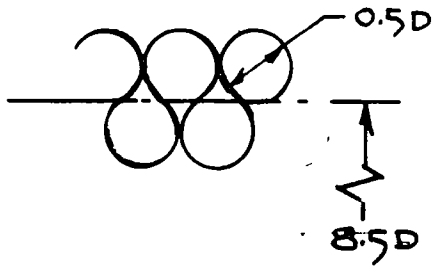
FWD HOUSING ASSEM (ALUM)

O.D = 12.0"
LENGTH = 12.0"
t_{WALL} = .150 (AVG)
t_{END} = .200

3.14 (11.85)(12)(.15)(0.100) = + 6.7
.785 (12)²(.200)(.100) = + 2.3
.785 (5)²(.200)(.100) = − 0.4
= 8.6#

BELLOWS (STEEL)

MEAN DIA = 8.5
LENGTH = 8.0
t = .018
NO. CONVOLUTIONS = 6



WT = 12(3.14)(85)(05)(314)(018)(285)
+ 2(3 14)(8.5)(.018)(.285) + 1 (END FTGS) = 39#

BRACKETS, FITTINGS ETC

END BEARING - BRACKET ASSEM	2.0	
TUBE SHIELD & BRACKETS	2 0	
EXTENSION LIMIT SWITCH	.2	
AFT LATCH	.5	
AFT LATCH SPRING	.1	
PINS (4)	4	
RETAINER	.4	
END CAP FITTING & LATCH	2.0	19.8#
FLEX LINES	4.0	
BULKHEAD FITTINGS	.8	
HOSE BRACKET	.9	
FLEX LINE GUIDE	2.0	
GUIDE BEARINGS (2)	.5	
TUBE ASSEMBLIES (4)	2 0	
AFT STATIONARY ATT BRACKET	2.0	

③ DATA MANAGEMENT	13.			
CENTRAL COMPUTER	14.	85.	4	340.
SYSTEM CONTROL UNIT	15.	7.	1	7.
MASS MEMORY	18.	16.	2	32.
AREA DIU'S	17.	5.8	28	162
CREW STATION DIU'S	17.	5.7	20	114.
IMU DIU'S	17.	5.	4	20.
DATA BUS	*			36.
MAINTENENCE RECORDER	19.	50.	2	100.
INPUT/OUTPUT CONTROL UNIT	16.	6.	4	24.
SUBTOTAL EQUIPMENT				(835.)
CIRCUITRY WT = $.039(835)^{1.298}$ =				242.
LOCAL MTG STR WT = $.412(835)^{.65}$ =				33.
EQUIP BAY STR WT = $1.35(835)^{.65}$ =				107.
TOTAL DATA MANAGEMENT				1217. LB

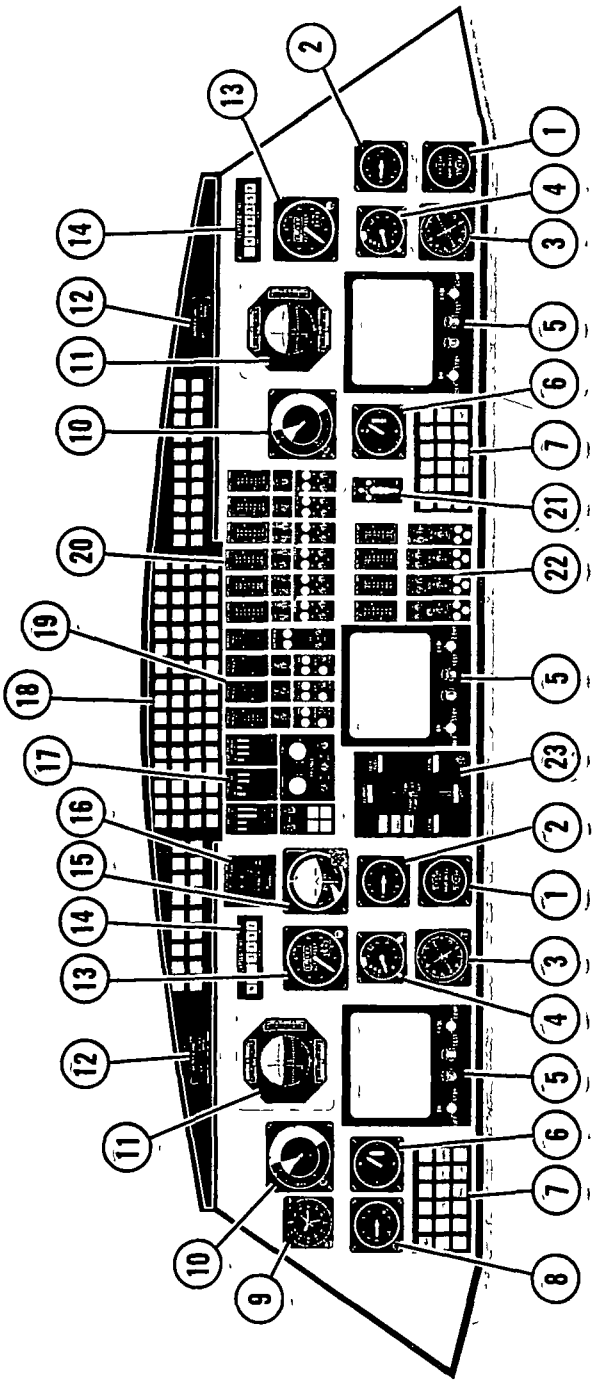
* BASED ON GROSS EST OF 2000' (4) WIRE TWISTED SHIELDED @ 18#/1000.

WEIGHT SUBSTANTIATION

ITEM	REF. NO. PG 2.13.-13	UNIT WEIGHT	QTY	TOTAL WEIGHT
④ COMMUNICATIONS & NAVAIDS	20			
AUDIO CONTROL CENTER	22	12.	3	36.
UHF TRANSCEIVER	24.	12.	3	36.
UHF ANTENNA	25.	13.	3	39.
UHF ANT WINDOW	*	15.3	3	46.
DME RECEIVER	26.	30.	3	90.
DME ANTENNA	25.	1.	4	4.
DME ANT WINDOW	*	12.5	4	50.
GLIDE SLOPE RECEIVER	27.& 28.	4.	3	12.
GLIDE SLOPE ANTENNA	25.	2.	3	6.
GS ANT WINDOW	*	11.	3	33.
VOR/LOCALIZER RECEIVER	27.& 28.	20.	3	60.
VOR/LOC ANTENNA	25.	8.	4	32.
VOR/LOC ANT WINDOW	*	16.5	4	66.
RADIO ALTIMETER	29.	21.	3	63.
ALTIMETER ANTENNA	25.	1.	6	6.
ALT ANT WINDOW	*	11.8	6	71.
ATC TRANSPONDER	31.	20.	1	20.
ATC ANTENNA	25.	1.	1	1.
ATC ANT WINDOW	*	13.	1	13.
SUBTOTAL EQUIPMENT				(684.)
CIRCUITRY WT = .039 (684. – 279 LB ANT WIND'S)$^{1.298}$				95.
LOCAL MTG STR WT = .412 (684. – 367 LB ANT & WIND'S)$^{.65}$				17.
EQUIP BAY STR WT = 1.35 (684. – 367 LB ANT & WIND'S)$^{.65}$				57.
TOTAL COMMUNICATIONS & NAVAIDS				853 LB

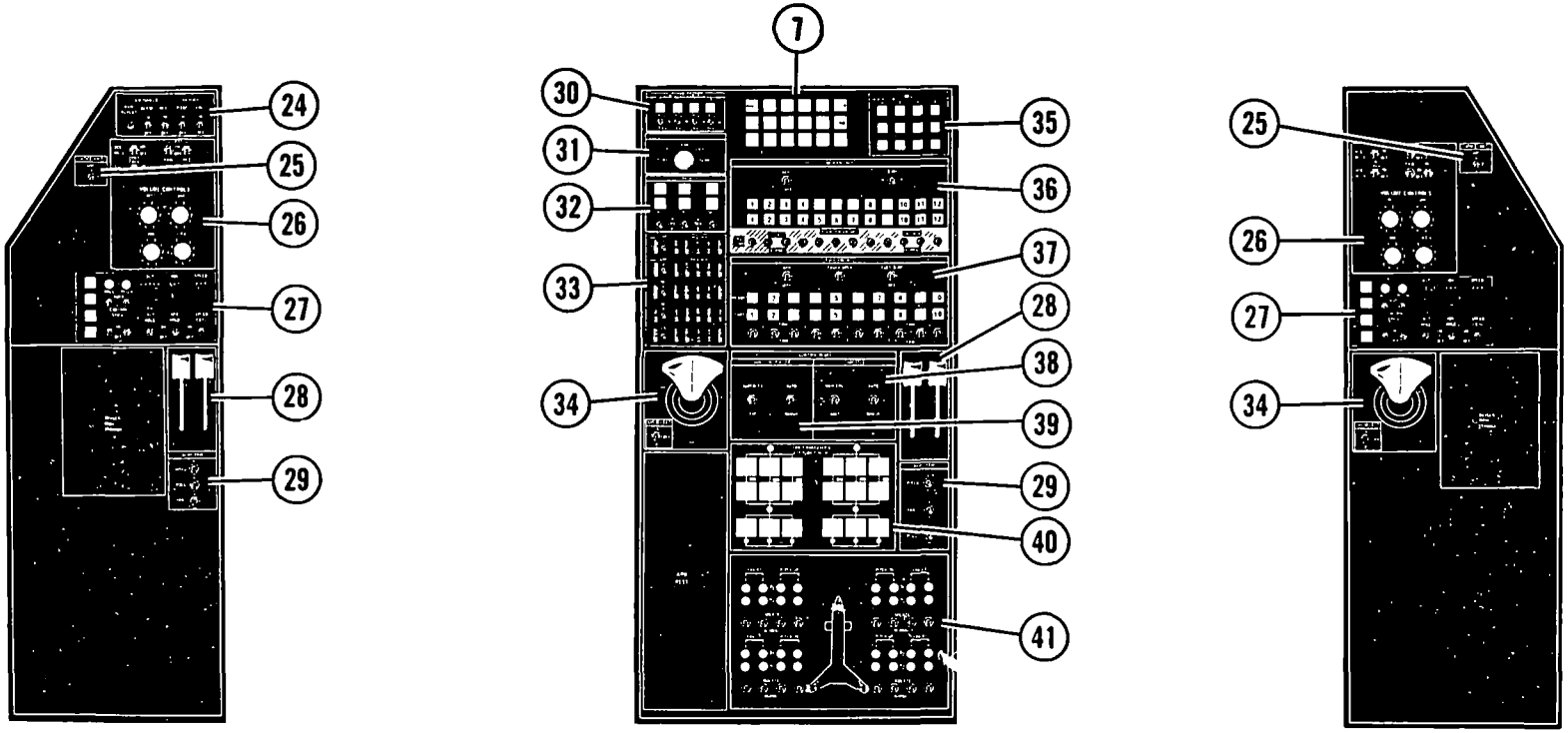
* SEE PART II PAGES 2.13-28 – 2.13-33

BOOSTER DISPLAYS & CONTROLS



1 DUAL DME
2 RATE OF DESCENT INDICATOR
3 HSI
4 RADIO ALTIMETER
5 CRT
6 ANGLE OF ATTACK
7 COMPUTER KEYBOARD
8 ACCELEROMETER
9 AIRCRAFT CLOCK
10 MACH/AIR SPEED INDICATOR
11 ATTITUDE DISPLAY INDICATOR
12 MASTER ALARMS
13 PRESSURE ALTIMETER
14 ELAPSED TIME
15 STANDBY ATTITUDE INDICATOR
16 SURFACE POSITION INDICATOR
17 ECLS PANEL
18 EMERGENCY, CAUTION AND WARNING INDICATORS
19 HYDRAULICS PANEL
20 APU PANEL
21 LANDING GEAR CONTROL
22 ELECTRICAL PANEL
23 FUEL MANAGEMENT PANEL

BOOSTER DISPLAYS AND CONTROLS (Continued)



24 WINDSHIELD AND DE-ICE CONTROLS
25 VOICE TRANSMITTER SELECT
26 VOICE CONTROL CENTER
27 AUTOPILOT
28 THROTTLES
29 AERODYNAMIC TRIMS
30 COMPUTER CONTROL
31 GUIDANCE MODE SELECTOR
32 COMMUNICATIONS CONTROL
33 FREQUENCY SELECTOR
34 SIDE CONTROLLER
35 IMU CONTROL PANEL
36 MAIN ENGINES PANEL
37 CRUISE ENGINES PANEL
38 THROTTLE MODE SELECTOR
39 SIDE CONTROLLER MODE SELECTOR
40 ATTITUDE CONTROL PROPULSION
41 REACTION THRUSTERS ISOLATION PANEL

WEIGHT SUBSTANTIATION

SEE PAGE 2.13.18 SOURCE DATA & REFERENCES 30a THRU m

⑤ DISPLAYS & CONTROLS - SEE PAGES 2.13-7 & -8 FOR ITEM NO.

ITEM NO.	ITEM	TOTAL WEIGHT
	CENTER FRONT PANEL	(166.0)
(17)	ECLS PANEL	17.1
(20)	APU/ALT PANEL	18.4
(16)	SURFACE POSITION INDICATOR	5.0
(21)	LAND GEAR LEVER/LIGHTS	3.0
(22)	ELECT. POWER PANEL	12.4
(19)	HYDRAULICS/BRAKES PANEL	11.9
(18)	EMERGENCY/CAUTION/WARNING	10.2
(23)	FUEL MANAGEMENT PANEL	3.0
(5)	VIDEO DISPLAYS	85.0
	COMMAND PILOT FRONT PANEL	(126.4)
(9)	AIRCRAFT CLOCK	1.5
	FLIGHT GROUP DIAL INDICATORS	
(10)	MACH/AIRSPEED	3.5
(6)	ANGLE OF ATTACK	2.9
(8)	ACCELEROMETER	2.0
(3)	HORIZ. SITUATION IND (HSI)	6.5
(4)	RADIO ALTIMETER	2.5
(2)	RATE OF DESCENT	2.3
(13)	PRESSURE ALTIMETER	2.0
(1)	DISTANCE MEASURE (DME) DIAL	2.5
(14)	ELAPSED TIME INDICATOR	1.5
(12)	MASTER ALARM LITES	.2
(5)	VIDEO DISPLAYS	85.0
(7)	COMPUTER KEYBOARD	3.0
(11) (15)	ATTITUDE DISPLAY IND	11.0

WEIGHT SUBSTANTIATION

DISPLAYS & CONTROLS – SEE PAGES 2.13-7 & -8 FOR ITEM NO.

ITEM NO	ITEM	TOTAL WEIGHT
	PILOT FRONT PANEL	(122.9)
	FLIGHT GROUP DIAL INDICATORS	
(10)	MACH/AIRSPEED	3.5
(6)	ANGLE OF ATTACK	2.9
(3)	HORIZ. SITUATION IND(HSI)	6.5
(4)	RADIO ALTIMETER	2.5
(2)	RATE OF DESCENT	2.3
(13)	PRESSURE ALTIMETER	2.0
(1)	DISTANCE MEASURE (DME) DIAL	2.5
(14)	ELAPSED TIME INDICATOR	1.5
(12)	MASTER ALARM LITES	.2
(5)	VIDEO DISPLAYS	85.0
(7)	COMPUTER KEYBOARD	3.0
(11)	ATTITUDE DISPLAY IND	11.0
	COMMAND PILOT OUTBOARD PANEL	(19.1)
(24)	WINDSHIELD/ANTI-ICE	.5
(25)(26)	VOICE COMM. CONTROL	2.0
(27)	AERO AUTOPILOT PANEL	4.3
(28)	THROTTLES	12.0
(29)	AERO TRIM SWITCH	.3
	PILOT OUTBOARD PANEL	(25.3)
(25)(26)	VOICE COMM CONTROL	2.0
(27)	AERO AUTOPILOT PANEL	4.3
(34)	SIDE STICK CONTROLLER	19.0

WEIGHT SUBSTANTIATION

DISPLAYS & CONTROLS – SEE PAGES 2.13-7 & -8 FOR ITEM NO.

ITEM NO	ITEM	TOTAL WEIGHT
	CENTER CONSOLE PANEL	(63.3)
(7)	COMPUTER KEY BOARD	3.0
(30)	COMPUTER CONTROL PANEL	.8
(31)	GUIDANCE MODE SELECTOR	.3
(32) (33)	COMMUNICATIONS/NAVAIDS PANEL	11.4
(34)	SIDE STICK CONTROLLER	19.0
(35)	IMU CONTROL PANEL	1.2
(36)	MAIN ENGINE CONTROL	3.8
(37)	ABES MANAGEMENT PANEL	3.9
(28)	THROTTLES	12.0
(38)	THROTTLE MODE SELECTOR	.4
(40)	ACPS PANEL	2.4
(29)	AERO TRIM SWITCH	.3
(41)	ACPS THRUSTER ISOLATION	4.8
	FLOOR AREA	(50.0)
	CMD PLT RUD/BR/NWS PEDALS	25.0
	PILOT RUD/BR/NWS PEDALS	25.0
	OVERHEAD PANEL (ESTIMATED)	(40.0)
	WINDOW FRAME MOUNT	(6.0)

WEIGHT SUBSTANTIATION

DISPLAYS & CONTROLS

SUMMARY

CENTER FRONT PANEL	166.0
COMMAND PILOT FRONT PANEL	126.4
PILOT FRONT PANEL	122.9
COMMAND PILOT OUTBOARD PANEL	19.1
PILOT OUTBOARD PANEL	25.3
CENTER CONSOLE PANEL	63.3
FLOOR AREA	50.0
OVERHEAD PANEL	40.0
SUBTOTAL EQUIPMENT	(613.0)
WINDOW FRAME MOUNT	6.0
CIRCUITRY WT = $.039(613)^{1.298}$ =	161.9
LOCAL MTG STR. = $.412\,(613)^{.65}$ =	26.7
COCKPIT PANELS	*
TOTAL DISPLAYS & CONTROLS	(807.6)

* SEE SECTION 2.15 BOOSTER PERSONNEL PROVISIONS

2.13. Avionics - Continued

LIST OF REFERENCES & DATA SOURCES

1.	Part II Pg's 2.13-5 and -6 Block Diagram and Functions Chart; Guidance and Navigation Item 1.
2.	Four responses (Singer-Kearoff Div., Delco Electr,, Honeywell, Litton/ Guidance and Control Div.) to inertial measurement RFTI No. 008.
3.	Five responses (ITT Aerospace/Optical Div., Kolsman Instrument, Northrop Corp.,Quantic Industries, TRW, Inc.) to gimballed star tracker RFTI No. 043.
4.	Three responses (Barnes Engineering, TRW Systems, Quantic Industries, Inc.) to Earth horizon sensor RFTI No. 010.
5.	Navigation Base Estimated assuming similarity to Apollo equipment.
6.	Part II Pg's 2.13-5 and -6 Block Diagram and Functions Chart; Flight Control System Item 2.
7.	Four responses (Sperry Rand, Lear Seigler Inc., Honeywell Inc., Northrop Corp.) to thruster electronics RFTI No. 026-9 fwd & -19 aft.
8.	Five responses (Bendix Corp., Sperry Rand Corp., Lear Siegler Inc., Honeywell Inc., Northrop Corp.) to TVC electronics RFTI No. 029.
9.	Four Responses (Bendix, Sperry Rand, Honeywell, Northrop Corp.) to rate gyro RFTI No. 030.
10.	Two responses (Sperry, Kollsman) to total pressure and temperature sensor RFTI No. 031.
11.	Four responses (Systron Donner, Honeywell, Bendix, Northrop Corp.) to two-axis accelerometer package RFTI No. 035.
12.	Two responses (Sperry, Kollsman) to static pressure sensor RFTI No. 032.
13.	Part II Pg's 2.13-5 and -6 Block Diagram and Functions Chart; Data Management Item 3.
14.	Eight responses (Hughes Aircraft, IBM, Control Data, Delco Electronics, Raytheon, RCA, Singer-Kearfott, Sperry-Univac) to DMS computer RFTI No. 011. The central computer unit is similar to the F-15 computer with enlarged storage cpability (65K) and modified for 120 VDC power and liquid cooling.
15.	Seven responses (Same as 14 above except without Sperry-Univac) to DMS System Control Unit RFTI No. 012.
16.	Eight responses (same as 14 above) to DMS Input/Output Control Unit RFTI No. 013.
17.	Nine responses (Same as 14 above except without IBM and in addition Bendix, SCI Electronics) to DMS digital interface unit (DIU) RFTI No. 015. Also: the DIU weights are verified by F-15 data.
18.	One response (Hughes Aircraft) to DMS mass storage RFTI No. 014. Also, mass memory unit weight is verified by Gemini and DC-10 hardware data.
19.	Three responses (Leach Controls, Lockheed Electronics, Odetics, Inc) to maintenance recorder RFTI No. 016. Also, maintenance recorder weight is verified by Apollo and DC-10 hardware data.
20.	Part II Pg's 2.13-5 and -6 Block Diagram and Functions Chart; Communications and Navaids Item 4.
21.	Three responses (Collins Radio, TRW, Inc., Philco-Ford-WDL Div.) to S-band and ranging equipment RFTI No. 022. Also, NASA data on Unified S-band equipment and Air Force space ground link system.
22.	One response (Collins Radio) to audio control center RFTI No. 025. Also, weight is verified by Apollo hardware data.
23.	Remote Intercom weight comes from Skylab hardware data.

24.	Four responses (Collins Radio, ECI, RCA, King Radio) to UHF transceiver RFTI No. 024. Typical weight from Collins Part No. 719E-1 or Magnavox Part No. 713CA.
25.	Three responses (Litton-Amecom Div., Transco Products, Electronic Resources) to high temperature antenna RFTI No. 041.
26.	Three responses (Collins Radio, RCA Electromagnetic and Aviation, King Radio) to distance measuring-equipment RFTI No. 036. Typical weight from Collins Part No. 860E-3 or King Radio Part No. KDM 7000.
27.*	Two responses (Bendix, Avionics Div, Collins Radio) to ILS receiver RFTI No. 037. Typical weight from Collins Part No. ILS-70 or Bendix Part No. RIA-32A.
28.*	Three responses (Bendix, Avionics Div., Collins Radio, Raytheon Equip. Div.) to VOR Receiver RFTI No. 023. Typical weight from Collins Part No. 51RV-2B or Bendix Part No. RVA-33A.
29.	Two responses (Bendix, Avionics Div., Collins Radio) to radio altimeter RFTI No. 038. Typical weight from Collins Part No. AL-101 or Bendix Part No. ALA-51A.
30.	Displays and Controls a. General - See item 5 pg's 2.13.4 and .5. b. Rpt. No. PR1057, Technical Information for Space Shuttle Video Display System, dated 21 April 1971, prepared by Norden Division of United Aircraft Corp. Norwalk, Connecticutt. (Detail Rpt contains 17 sections, approx. 130 pg's plus six appendices.) c. Detail weight tabulation of cathode ray tube indicator unit is shown on page 3-14 of Rpt. PR1057. Total weight is 30.63 lb which is broken into 24 separate items quoted to X.XX. This data is considered proprietary and therefore cannot be reproduced here. d. Detail weight tabulation of multifunction symbol generator unit is shown on page 4-28 of Rpt. PR1057. Total weight is 29.89 lb which is broken into 11 separate components plus 12 logic modules quoted to X.XX. This data is considered proprietary and therefore cannot be reproduced here. e. Questions relating to items b, c, d and f can be directed to: Mr. C. J. Richardson Norden Video Systems Senior Sales Engineer Phone: 203-838-4471, Ext. 4685. f. The camera reader microviewer weight is also based on data contained in Rpt. PR1057. g. In addition to Norden, there have been nine other responses (Astronautics Corp. of Amer., Bendix Nav. & Cntl Div., Colins, GE Avionics, Kaiser Aerospace Elec. Corp., Loral, Raytheon, Sperry Rand, Westinghouse) to video displays RFTI No. 017. h. Attitude display indicator weight is based on Apollo CSM/LEM hardware data. i. Vertical scale indicator (VSI) weights are based on (Scale) Gemini/Apollo hardware and (Tape) F-15 hardware.

* Recent system changes show glideslope Rcvr and VOR/LOC rcvr vs orig. ILS and VOR; equip. is virtually comparable, net wt. change is +3 lb/unit or +9 lb total.

	j. Flight group dials, time reference sys., etc. is based on general aircraft/spacecraft devices. k. Switches, twist knobs, etc. are general aircraft, spacecraft equip. l. Centerstick/rudder pedals are based on F-15 weight data. m. Rotational and translational hand controller weights are based on Apollo CSM hardware data.
31.	ATC transponder typical weight from Collins Part No. 621A-6ATC or Bendix Part No. TRA-63A.

2.13. AVIONICS - WEIGHT SUMMARY

1 2 3		QTY	UNITS	DIGITAL I/F UTS	CIRC.	COOLING	ANTENNAS	INSTAL.	TOTAL
4									
5	Guidance & Navigation		(140)	(N/A)	(24)	(N/A)	(N/A)	(114)	278
6	IMU	4	140						
7									
8									
9									
10									
11	Navigation Base							80	
12	Mounting Struct.							10	
13									
14	Eq. Bay Struct.							24	
15									
16	Circuitry				24				
17									
18									
19									
20									
21	Flight Control		(650)	(N/A)	(175)	(N/A)	(N/A)	(334)	1159
22	Thruster Elect.-ACPS	10	70						
23	TVC Actuator Elect.	12	342	*					
24	Actuator Elect.	8	184	*					
25	Rate Gyro Pkg.	4	16						
26	Tot. Temp & Press Snsr	4	10						
27	Accelerometer	4	6						
28	Static Press Sensor	4	10						
29	Pitch α Sensor	4	4	*Note: Ea. Elect. Unit Contains					
30	Sideslip Sensors	4	4	(1 DIU @ approx. 1# ea.					
31	Mounting Struct.							28	
32	Eq. Bay Struct.							91	
33	Norm. Press. Sensors	4	4						
34	Circuitry				175				
35	Actuator Assem.	2						215	
36									
37	Data Management		(539)	(296)	(242)	(N/A)	(N/A)	(140)	1217
38	Central Computer	4	340						
39	System Control Unit	1	7						
40	Mass Memory Mech.	2	20						
41	Mass Memory Elect.	2	12						
42	Area DIU's	28		162					
43	Crew Station DIU's	20		114					
44	IMU DIU's	4		20					
45	Data Bus		36						
46	Maintenance Recorder	2	100						
47	Input/Output Cntl Unit	4	24						
48	Mounting Struct.							33	
49	Eq. Bay Struct.							107	
50	Circuitry				242				
51									
52	Subtotals This Pg.		1329	296	441	(N/A)	(N/A)	588	2654

2.13. Avionics Weight Summary - Cont.

		QTY	UNITS	DIGITAL I/F UTS	CIRC.	COOLING	ANTENNAS	INSTAL.	TOTAL
56	Communications & Navaids		(317)	(N/A)	(95)	(N/A)	(88)	(353)	853
57							9		
58	Audio Control(Enter)	3	36						
59									
60	UHF Transceiver	3	36				*(3)39	46	
61	DME Receiver	3	90				*(4) 4	50	
62	Glideslope Receiver	3	12				*(3) 6	33	
63	VOR/LOC Receiver	3	60				*(4)32	66	
64	Radio Altimeter	3	63				*(6) 6	71	
65	Mounting Struct.							17	
66	Eq. Bay Struct.							57	
67	Circuitry				95				
68	ATC Transponder	1	20				*(1) 1	13	
69									
70	Config. Seq		See Data Management Line Item No. 37 Previous Page						
71									
72	Instrumentation		" "		"	" "	" "	"	"
73									
74	Displays & Controls		(613)	(N/A)	(162)	(N/A)	(N/A)	(33)	808
75	Center Front Panel	1	107						
76	Command Pilot Panel	1	131						
77	Pilot Panel	1	130						
78	Cmd Pilot OBD Panel	1	28						
79	Pilot OBD Panel	1	21						
80	Center Console Panel	1	144						
81	Floor Area	2	90						
82	Overhead Panels	1	30						
83	Docking Station	1	13						
84	Mounting Struct.							27	
85	Window Frame Mount							6	
86	Cockpit Panels		See Personnel Provisions Code No. 15 Line Item No. 53						
87	Circuitry				162				
88									
89									
90									
91									
92	Subtotals this page		(930)	(N/A)	(257)	(N/A)	(88)	(386)	(1661)
93									
94	Subtotals previous page		1329	296	441	(N/A)	(N/A)	588	2654
95									
96	Totals		(2259)	(296)	(698)	(N/A)	(88)	(974)	(4315)
97	Contingency								612
98	Total - Avionics								4927

* No's in ( ) indicate Qty

ENVIRONMENTAL CONTROL 2058 LB

	WEIGHT-LB	PAGE NO.
GAS SUPPLY SYSTEM (DRY)	120	2.14-6
ATMOSPHERE SUPPLY	[67]	
AIR TANKS (2)	38	
PRESSURE RELIEF VALVE (2)	5	
PRESSURE REGULATOR (2)	4	
SHUT-OFF VALVE (2)	3	
CHECK VALVE (2)	2	
DISCONNECT (2)	1	
TEMP TRANSDUCERS (6)	2	
PRESSURE TRANSDUCERS (9)	12	
AIR	*	
OXYGEN SUPPLY	[33]	
OXYGEN TANK	8	
PRESSURE RELIEF VALVE	3	
PRESSURE REGULATION	2	
SHUT-OFF VALVE	2	
CHECK VALVE (2)	2	
DISCONNECT	1	
MASK CONNECTIONS (2)	1	
FACE MASK AND HOSE (2)	5	
TEMP TRANSDUCERS (3)	1	
PRESSURE TRANSDUCERS (6)	8	
OXYGEN	*	
PLUMBING & PLUMBING SUPPORT	[6]	
CIRCUITRY & MISC	[5]	
MOUNTING STRUCTURE	[9]	

*INCLUDED IN RESIDUALS

	WEIGHT-LB	PAGE NO.
AIR CYCLE SYSTEM & PRESSURE CONTROL	308	2.14-10 & 11
AIR CYCLE SYSTEM	[106]	
AIR CYCLE PACKAGE	(37)	
INTERCOOLER (3)	14	
TURBINE/COMP (3)	11	
TEMP CONTROL VALVE (3)	8	
TEMP TRANSDUCERS (12)	4	
CONTROLLER	(5)	
CHECK VALVE - CABIN SUPPLY (4)	(4)	
REGULATOR/SHUT-OFF VALVE (3)	(12)	
WATER SEPARATOR (3)	(7)	
DISCONNECT/CHECK VALVE - AGE	(1)	
PRECOOLER ASSY	(9)	
JP-4 PRECOOLER	4	
TEMP CONTROL VALVE	3	
TEMP TRANSDUCERS (4)	1	
PRESSURE TRANSDUCERS (1)	1	
CABIN AIR DISTRIBUTION	(13)	
OVERHEAD DIFFUSER	2	
TOGGLE VALVE-FOOT OUTLET (2)	1	
LOUVERED OUTLETS (2)	1	
TEMP TRANSDUCERS (3)	1	
PRESSURE TRANSDUCERS (6)	8	
RAIN REMOVAL ASSY	(18)	
OUTLET NOZZLE ASSY	9	
REGULATOR	3	
SHUT-OFF VALVE (2)	5	
TEMP TRANSDUCER (3)	1	
PRESSURE CONTROL	[22]	
PRESSURE CONTROL INSTL	(22)	
EMERG SHUT-OFF VALVE (3)	6	
PRESSURE REGULATOR (3)	8	
SAFETY VALVE (3)	8	

	WEIGHT-LB	PAGE NO.
DUCTING & DUCTING SUPPORT	[126]	
CIRCUITRY & MISC	[12]	
MOUNTING STRUCTURE	[10]	
PACKAGING ALLOWANCE	[32]	
HEAT TRANSPORT SYSTEM (DRY)	455	2.14-14
FREON SUPPLY & CONDITIONING	[148]	
PUMP PACKAGE (2)	(82)	
FILTER ASSY (2)	(8)	
SERVICE CONNECTIONS (4)	(1)	
GH_2 HEAT EXCHANGER ASSY	(29)	
JP-4 HEAT EXCHANGER	(6)	
REGEN. HEAT EXCHANGER (2)	(6)	
TEMP CONTROL VALVES (2)	(3)	
TEMP CONTROLLER (2)	(4)	
GROUND COOLING ASSY	(9)	
GROUND HEAT EXCHANGER	4	
TEMP CONTROL VALVE	3	
TEMP TRANSDUCERS (2)	1	
DISCONNECTS (2)	1	
COLD PLATE/COLD RAIL INSTL	[112]	
COLD PLATES - COCKPIT (2)	18	
COLD PLATES - FORWARD (3)	27	
COLD PLATES - INTERTANK (2)	18	
COLD PLATE - MIDSHIP (1)	9	
COLD PLATES - UPPER AFT (2)	18	
COLD PLATES - LOWER AFT (2)	18	
TEMP TRANSDUCERS (12)	4	
INSULATION - FREON LINES	[43]	
PLUMBING & PLUMBING SUPPORT	[87]	
CIRCUITRY & MISC	[15]	
MOUNTING STRUCTURE	[15]	
PACKAGING ALLOWANCE	[35]	
FREON	*	

*INCLUDED IN RESIDUALS

	WEIGHT-LB	PAGE NO.
CABIN INSULATION	172	2.14-18
FLOOR (1" GHF)	29	& 19
FORWARD BULKHEAD (1" GHF)	4	
AFT BULKHEAD (1" GHF)	23	
LOWER SIDEWALL (2" GHF)	29	
UPPER SIDEWALL (2" GHF)	21	
CEILING (2" GHF)	36	
BONDING	30	
PURGE SYSTEM	816	2.14-23*
CONTINGENCY - 10 PERCENT	187	

*SEE DISCUSSION ON PAGE 2.14-22

WEIGHT SUBSTANTIATION - ENVIRONMENTAL CONTROL

THE ENVIRONMENTAL CONTROL AND LIFE SUPPORT (ECLS) SYSTEM WEIGHTS, EXCLUDING PURGE SYSTEM WEIGHTS, REPRESENT THE SYSTEM SHOWN ON DRAWING NO. 256-20-0029, SCHEMATIC - COCKPIT AND AVIONICS ECLS. THIS SYSTEM PROVIDES A SHIRTSLEEVE ENVIRONMENT FOR THE CREW, THERMAL CONTROL FOR AVIONICS, AND PROVISIONS FOR WINDSHIELD RAIN REMOVAL AND DEFOGGING.*

AS INDICATED IN THE FOLLOWING PAGES, ALL WEIGHTS ARE BASED ON EXISTING OR SIMILAR HARDWARE OR CALCULATED FROM INFORMATION OBTAINED FROM DRAWINGS AND LAYOUTS.

THE ENVIRONMENTAL CONTROL SYSTEM CONSISTS OF THE MAJOR SUB-SYSTEMS SHOWN IN THE FOLLOWING TABLE.

14	ENVIRONMENTAL CONTROL	2058
	GAS SUPPLY SYSTEM (DRY)	120
	AIR CYCLE & PRESSURE CONTROL SYSTEM	308
	HEAT TRANSPORT SYSTEM (DRY)	455
	CABIN INSULATION	172
	PURGE SYSTEM	816
	CONTINGENCY	187

* SEE MDAC MEMO NO. SSPI-E450-588, ENVIRONMENTAL CONTROL & LIFE SUPPORT

WEIGHT SUBSTANTIATION

ITEM	SEE PAGE 2.14-		SCHEMATIC REF. NO.	UNIT WT	QTY	TOTAL WT
GAS SUPPLY SYSTEM						120
ATMOSPHERE SUPPLY						[67]
AIR TANKS	2.14-7	(1)	29-6-2	19.0	2	38
PRESS. RELIEF VAL		(2)	29-6-3	2.5	2	5
PRESS. REGULATOR		(2)	29-6-5	2.0	2	4
SHUT-OFF VALVE		(2)	29-6-4	1.5	2	3
CHECK VALVE		(2)	29-6-7	0.7	2	2
DISCONNECT		(2)	29-6-8	0.3	2	1
TEMP. XDUCERS		(3)		0.3	6	2
PRESS. XDUCERS		(3)		1.3	9	12
AIR						*
OXYGEN SUPPLY						[33]
OXYGEN TANK	2.14-7	(1)	29-6-1	8.0	1	8
PRESS RELIEF VAL.		(2)	29-6-3	2.5	1	3
PRESS. REGULATOR		(2)	29-6-5	2.0	1	2
SHUT-OFF VALVE		(2)	29-6-4	1.5	1	2
CHECK VALVE		(2)	29-6-7	0.7	2	2
DISCONNECT		(2)	29-6-8	0.3	1	1
MASK CONNECTIONS		(4)	29-6-9	0.3	2	1
FACE MASK & HOSE		(4)		2.7	2	5
TEMP. XDUCERS		(3)		0.3	3	1
PRESS. XDUCERS		(3)		1.3	6	8
OXYGEN						*
PLUMBING & SUPPORT	2.14-9					[6]
CIRCUITRY & MISC.	2.14-9					[5]
MOUNTING STRUCTURE	2.14-9					[9]

* AIR & OXYGEN WEIGHTS SHOWN ON PAGE 2.14-17 ARE INCLUDED IN RESIDUALS

WEIGHT SUBSTANTIATION - ENVIRONMENTAL CONTROL

(1) TANK WEIGHT FROM HAMILTON STANDARD BASED ON EXISTING TANK DATA. SEE DESIGN NOTE NO. IM-0-EAST-ECLS-005, ENVIRONMENTAL CONTROL & LIFE SUPPORT, ATMOSPHERE STORAGE STUDY FOR ECLS, 16 NOVEMBER 1970, AND HAMILTON STANDARD REPORT NO. HS-SSH-MDAC/005, BOOSTER ENVIRONMENTAL CONTROL/LIFE SUPPORT, NOVEMBER 1970

(2) HAMILTON STANDARD ESTIMATE. SCALED FROM SIMILAR LM & MOL VALVES, REGULATORS & DISCONNECTS.

(3) TEMPERATURE & PRESSURE TRANSDUCER WEIGHTS BASED ON MOL & SKYLAB HARDWARE DATA.

(4) FACE MASK, HOSE, & CONNECTION WEIGHTS WERE OBTAINED FROM SKYLAB HARDWARE DATA.

(5) INTERCOOLER WEIGHT IS A HAMILTON STANDARD ESTIMATE BASED ON SIMILAR HARDWARE

(6) THE TURBINE/COMPRESSOR WEIGHT WAS SCALED FROM B-58 & CESSNA DATA.

(7) TEMPERATURE CONTROL VALVE SIMILAR TO CESSNA CITATION - PART NO. 738491

(8) CONTROLLER WEIGHT IS A CONCEPT ESTIMATE BASED ON SIMILAR HARDWARE.

(9) CHECK VALVE WEIGHT WAS SCALED FROM AIRESEARCH PART NO. 107204

(10) REGULATOR/SHUT-OFF VALVE SCALED FROM AIRESEARCH PART NO. 108114

(11) WATER SEPARATOR SIMILAR TO CESSNA CITATION HARDWARE.

(12) JP-4 PRECOOLER WEIGHT WAS SCALED FROM A-7A PN-HS 598199.

WEIGHT SUBSTANTIATION - ENVIRONMETAL CONTROL

(13) CONCEPT ESTIMATE BASED ON SIMILAR HARDWARE.

(14) NOZZLE ASSEMBLY WEIGHT OBTAINED FROM DC-8 HARDWARE DATA

(15) REGULATOR WEIGHT SCALED FROM AIRESEARCH PART NO 106596.

(16) SHUT-OFF VALVE WEIGHT SCALED FROM AIRESEARCH PART NO. 104338

(17) PUMP PACKAGE SCALED FROM MOL HARDWARE DATA.

(18) FILTER ASSEMBLY WEIGHT BASED ON SIMILAR SKYLAB HARDWARE.

(19) GH_2, JP-4, & REGENERATIVE HEAT EXCHANGER WEIGHTS ARE HAMILTON STANDARD ESTIMATES BASED ON SIMILAR HARDWARE.

(20) TEMPERATURE CONTROL VALVE WEIGHT SCALED FROM LM HARDWARE DATA.

(21) GROUND HEAT EXCHANGER WEIGHT SCALED FROM MOL HARDWARE DATA

(22) COLD PLATE WEIGHTS ARE BASED ON ACTUAL WEIGHT OF MOL HARDWARE

WEIGHT SUBSTANTIATION

GAS SUPPLY SYSTEM

PLUMBING & PLUMBING SUPPORT

ATMOSPHERE SUPPLY

PRESSURE = 3000 PSI
ULTIMATE SAFETY FACTOR = 2.5
(REF: SPACE SHUTTLE LEVEL II REQUIREMENTS
APPENDIX G - SPACE SHUTTLE STRUCTURAL
CRITERIA TP 3.2.2 b.)
LINE MATERIAL: ARMCO SS 21-6-9 $\sigma_{ULT} = 95{,}000$
LINE DIAMETER = 3/8"

$$t = \frac{F.S.\ PR}{\sigma} = \frac{2.5(3{,}000)(.1875)}{95{,}000} = .0148 \quad \text{USE } 0.028"$$

LENGTH 200" + 20% FOR ROUTING = 240"
WT = 240(.0087) = 2 LB

OXYGEN SUPPLY

PRESSURE = 3,000 PSI
LINE DIAMETER = 1/4" MATERIAL: ARMCO SS 21-6-9
t = 0.020 (SEE CALCULATIONS FOR ATMOS SUPPLY)
LINE LENGTH = 400 + 20% FOR ROUTING = 480"
WT = 480(.0041) = 1.97 USE 2 LB

SUPPORT & FITTINGS = (15% + 30%) OF 9 LB (15% ← SUPPORT; 30% ← FITTINGS) 2 LB

TOTAL PLUMBING & SUPPORT = **6 LB**

CIRCUITRY & MISC

$WT = .039(WT\ EQUIP)^{1.298}$
REF: SAWE TECH. PAPER 514, UNMANNED SPACECRAFT
WEIGHT ESTIMATION HANDBOOK, MAY 1965
BY: DONALD PENCE
WT EQUIP - VALVES & TRANSDUCERS ONLY
$WT = 039(42)^{1.298}$ = **5 LB**

MOUNTING STRUCTURE

$WT = .412(WT.\ EQUIP)^{.65}$
REF. MDC REPORT No. E0377, PART II, SECTION 2.13
$WT = .412(100)^{.65}$ = **9 LB**

WEIGHT SUBSTANTIATION

ITEM	SEE PAGE 2.14-		SCHEMATIC REF. NO.	UNIT WT	QTY	TOTAL WT
AIR CYCLE & PRESS. CONTROL						308
AIR CYCLE SYSTEM						[106]
AIR CYCLE PACKAGE			29-4			(37)
INTERCOOLER	2.14-7	(5)	29-4-1	4.5	3	14
TURBINE/COMPRESS.		(6)	29-4-2	3.5	3	11
TEMP. CONTROL VAL		(7)	29-4-3	2.5	3	8
TEMP. XDUCERS		(3)		0.3	12	4
CONTROLLER		(8)	29-3	5.0	1	(5)
CHECK VAL. CABIN SUP.		(9)	29-10	1.0	4	(4)
REG./SHUT-OFF VAL		(10)	29-8	4.0	3	(12)
WATER SEPARATOR		(11)	29-7	2.3	3	(7)
DISCON/CHECK VAL		(2)	29-11	1.0	1	(1)
PRECOOLER ASSY.						(9)
JP-4 PRECOOLER		(12)	29-15	3.5	1	4
TEMP. CONTROL VAL		(7)	29-14	2.5		3
TEMP. XDUCERS		(3)		0.3	4	1
PRESS. XDUCERS		(3)		1.3	1	1
CABIN AIR DISTRIB						(13)
OVRHD DIFFUSER	2.14-8	(13)	29-5-1	1.0	2	2
VALVE-FOOT OUTLET	2.14-8	(13)	29-5-2	0.4	2	1
LOUVERED OUTLETS	2.14-8	(13)	29-5-3	0.5	2	1
TEMP. XDUCERS	2.14-7	(3)		0.3	3	1
PRESS. XDUCERS	2.14-7	(3)		1.3	6	8
RAIN REMOVAL ASSY			29-1			(18)
OUTLET NOZZLE ASSY	2.14-8	(14)		9.0	1	9
REGULATOR	2.14-8	(15)	29-1-1	2.5	1	3
SHUT-OFF VALVE	2.14-8	(16)	29-1-2	2.5	2	5
TEMP. XDUCER	2.14-7	(3)		0.3	3	1

WEIGHT SUBSTANTIATION

AIR CYCLE & PRESSURE CONTROL (CONTINUED)

ITEM	SEE PAGE 2.14-	SCHEMATIC REF. NO.	UNIT WT	QTY	TOTAL WT
PRESSURE CONTROL					[22]
PRESS. CONTROL INSTL.		29-2			(22)
EMERG SHUT-OFF VAL	2.14-7 (2)	29-2-1	2.0	3	6
PRESS. REGULATOR	2.14-7 (2)	29-2-3	2.5	3	8
SAFETY VALVE	2.14-7 (2)	29-2-2	2.5	3	8
DUCTING & SUPPORT	2.14-12				[126]
CIRCUITRY & MISC.	2.14-13				[12]
MOUNTING STRUCTURE	2.14-13				[10]
PACKAGING ALLOWANCE	2.14-13				[32]

AIR CYCLE SYSTEM & PRESSURE CONTROL

DUCTING & DUCTING SUPPORT

AIR CYCLE SYSTEM

2.5" DIA. TITANIUM DUCT FROM CRUISE ENGINES TO FORWARD COMPARTMENT
LENGTH = 1,500" + 20% FOR ROUTING = 1,800"
PRESSURE = 200 PSI t = 0.022 MIN GAGE
$WT = 1,800(.0284) =$ 51 LB

2" DIA TITANIUM DUCT FROM AIR CYCLE PACKAGE TO RAIN REMOVAL NOZZLES
LENGTH = 300" + 20% FOR ROUTING = 360"
PRESSURE = 200 PSI t = 0.020 MIN GAGE
$WT = 360(.0225) =$ 8 LB

3" DIA. ALUMINUM DUCT FROM AIR CYCLE PACKAGE TO CABIN
LENGTH = 300" + 20% FOR ROUTING = 360"
PRESSURE = 100 PSI MAX t = 0.028 MIN GAGE
$WT = 360(.0264) =$ 10 LB

1" DIA. ALUMINUM DUCT FOR CABIN AIR DISTRIBUTION
LENGTH 360" + 30% FOR ROUTING = 470"
PRESSURE = 100 PSI MAX t = 0.028 MIN GAGE
$WT = 470(.0086) =$ 4 LB

PRESSURE CONTROL

4" DIA AL DUCT TO ATMOSPHERE DUMP OUTLET
LENGTH = 120" + 20% FOR ROUTING = 144"
t = 0.028 MIN GAGE
$WT = 144(.0991) =$ 14 LB

SUPPORT & FITTINGS

30% FOR FITTINGS
15% FOR SUPPORT
$WT = .45(87) =$ 39 LB

TOTAL PLUMBING & SUPPORT 126 LB

AIR CYCLE SYSTEM & PRESSURE CONTROL (CONT.)

CIRCUITRY & MISC

$WT = .039 (WT\ EQUIP.)^{1.298}$

SEE REFERENCE IN GAS SUPPLY SYSTEM

WT EQUIP = TURBINE/COMP., VALVES, CONTROLLER & TRANSDUCERS

$WT = .039(86)^{1.298} =$ **12 LB**

MOUNTING STRUCTURE

$WT = .412 (WT.\ EQUIP.)^{.65}$

SEE REFERENCE IN GAS SUPPLY SYSTEM

$WT = .412(128)^{.65} =$ **10 LB**

PACKAGING ALLOWANCE

$WT = 1.35 (WT.\ EQUIP)^{.65}$

REF: MDC REPORT NO. E0377, PART II, SECTION 2.13

$WT = 1.35(128)^{.65} =$ **32 LB**

WEIGHT SUBSTANTIATION

ITEM	SEE PAGE 2.14-		SCHEMATIC REF. NO.	UNIT WT	QTY	TOTAL WT
HEAT TRANSPORT SYSTEM						455
FREON SUPPLY & COND.						[148]
PUMP PACKAGE	2.14-8	(17)	29-17	41.0*	2	(82)
FILTER ASSY.	↓	(18)	29-20	4.0	2	(8)
SERVICE CONNECT	2.14-7	(2)	29-21	0.3	4	(1)
GH_2 HEAT EX	2.14-8	(19)	29-25	29.0	1	(29)
JP-4 HEAT EX	↓	(19)	29-22	6.0	1	(6)
REGEN. HEAT EX.	↓	(19)	29-23	3.0	2	(6)
TEMP. CONTROL VAL.	↓	(20)	29-24	1.5	2	(3)
TEMP. CONTROLLER	2.14-7	(8)	29-27&28	2.0	2	(4)
GROUND COOLING ASSY						(9)
GROUND HEAT EX	2.14-8	(21)	29-26	4.0	1	4
TEMP. CONTROL VAL.	↓	(20)	29-28	2.5	1	3
TEMP. XDUCERS	2.14-7	(3)		0.3	2	1
DISCONNECT	↓	(2)		0.3	2	1
COLD PLATES	↓					[112]
COCKPIT	2.14-8	(22)		8.8	2	18
FORWARD	↓	↓		8.8	3	27
INTERTANK	↓	↓		8.8	2	18
MIDSHIP	↓	↓		8.8	1	9
UPPER AFT	↓	↓		8 8	2	18
LOWER AFT	↓	↓		8.8	2	18
TEMP XDUCERS	2.14-7	(3)		0.3	12	4
INSULATION-FREON LINES	2.14-15					[43]
PLUMBING & SUPPORT	2.14-16					[87]
CIRCUITRY & MISC	2 14-16					[15]
MOUNTING STRUCTURE	2.14-16					[15]
PACKAGING ALLOWANCE	2.14-15					[35]
FREON						**

* INCLUDES ACCUMULATOR

** FREON WEIGHT SHOWN ON PAGE 2.14-17 IS INCLUDED IN RESIDUALS

HEAT TRANSPORT SYSTEM

INSULATION - FREON LINES

ALL LINES WILL HAVE 0.5" THICK INSULATION @ 2 LB/FT^3

3/4" LINES

$L = 1,152''$

INSULATION VOLUME $= (2.405 - .4418)IN^2(1,152\ IN) = 2,260\ IN^3$

3/8" LINES

$L = 9,180''$

INSULATION VOLUME $= (1.482 - .1104)IN^2(9,180\ IN) = 12,600\ IN^3$

1/2" LINES

$L = 5,550''$

INSULATION VOLUME $= (1.767 - .1963)IN^2(5,550\ IN) = 8,230\ IN^3$

TOTAL INSULATION VOLUME $= 23,090\ IN^3$

$= 13.4\ FT^3$

TOTAL INSULATION WT $= 2\ LB/FT^3(13.4\ FT^3) =$ 27 LB

BONDING:

AREA $= \pi[(.75)(1,152) + .375(9,180) + .5(5,550)] = 22,300\ IN^2$

$= 155\ FT^2$

WT $= 155\ FT^2(.1\ LB/FT^2) =$ 16 LB

TOTAL INSULATION & BONDING = **43 LB**

PACKAGING ALLOWANCE

$WT = 1.35(WT\ EQUIP)^{.65}$

REF: MDC REPORT NO. E0377, PART II, SECTION 2.13

$WT = 1.35(148^*)^{.65} =$ **35 LB**

* DOES NOT INCLUDE COLD PLATES

HEAT TRANSPORT SYSTEM

PLUMBING & PLUMBING SUPPORT

3/4" ALUMINUM LINES FROM PUMP PACKAGE TO TUNNEL SPLIT - SYSTEM HAS TWO CIRCUITS
LENGTH = 480"/CIRCUIT + 20% FOR ROUTING
= 2(576) = 1,152"
PRESSURE = 300 PSI ℓ = 0.028

WT = 1,152(.0064) = 8 LB

3/8" ALUMINUM LINES FROM TUNNEL SPLIT TO AFT COLD PLATES
LENGTH = 9,180"/CIRCUIT + 10% FOR ROUTING
= 2(9,598) = 9,180"
PRESSURE = 300 PSI ℓ = 0.028

WT = 9,180 (.0031) 29 LB

1/2" ALUMINUM LINES FROM TUNNEL SPLIT TO FORWARD COLD PLATES
LENGTH = 2,520"/CIRCUIT + 10% FOR ROUTING
= 2(2,772) = 5,550"
PRESSURE = 300 PSI ℓ = 0.028

WT = 5,550(.0042) = 23 LB

SUPPORT & FITTINGS

30% FOR FITTINGS, 15% FOR SUPPORT
WT = .45(60) = 27 LB

TOTAL PLUMBING & SUPPORT **87 LB**

CIRCUITRY & MISC

$WT = .039(WT\ EQUIP)^{1.298}$
SEE REFERENCE IN GAS SUPPLY SYSTEM
WT. EQUIP = PUMP PACKAGE, VALVES & TRANSDUCERS

$WT = .039(97)^{1.298}$ = **15 LB**

MOUNTING STRUCTURE

$WT = .412(WT.\ EQUIP)^{.65}$
SEE REFERENCE IN GAS SUPPLY SYSTEM

$WT = .412(260)^{.65}$ = **15 LB**

ENVIRONMENTAL CONTROL SYSTEM
(REF: SSPI-E450-588)

FREON VOLUME IN LINES

3/4" LINES

V = 1,152" (.3783 IN³/IN) = 437 IN³

3/8" LINES

V = 9,180" (.0799 IN³/IN) = 733 IN³

1/2" LINES

V = 5,550" (.1548 IN³/IN) = 860 IN³

TOTAL LINE VOLUME 2,030 IN³

FREON WEIGHT

LINES = 2,030 (.0535 LB/IN³)	=	11 LB
PUMP & ACCUMULATOR = 2 (6)	=	12 LB
JP-4 HT EX	=	3 LB
REGEN. HT EX = 2 (1.5)		3 LB
GH_2 HT EX =		5 LB
GROUND HT EX =		2 LB
COLD PLATES = 12 (1.5) =		18 LB
TOTAL WT OF FREON		54 LB

AIR

VOLUME = 0.9 FT³/BOTTLE - 2 BOTTLES
PRESSURE = 3,000 PSI ρ = 15.3 LB/FT³

WT = 2 (.9) (15.3) = 28 LB

OXYGEN

VOLUME = .118 FT³ - 1 BOTTLE
PRESSURE = 3,000 PSI ρ = 15.3 LB/FT³

WT = (.118) (17) = 2 LB

CABIN INSULATION

THE CABIN IS INSULATED WITH GLASS HEAT FELT (GHF) @ 4 LB/FT³

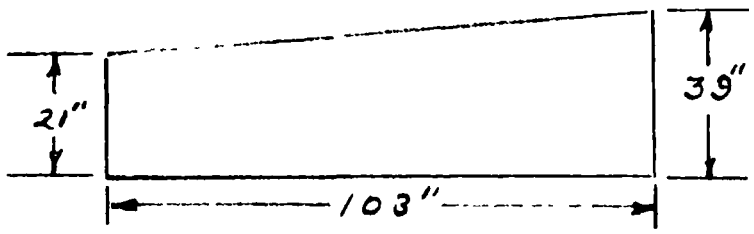
AREAS :

FLOOR
AREA = 86 FT²
(SEE CALCULATION - BODY GROUP)

AFT BLKHD
AREA = 68 FT²
(SEE CALCULATION - BODY GROUP)

FWD BLKHD
AREA = 12 FT²
(SEE CALCULATION - BODY GROUP)

LOWER SIDEWALL



$$\text{AREA} = \left(\frac{21+39}{2}\right)(103)/144 = 21.5 \text{ FT}^2/\text{SIDE}$$

TOTAL LOWER SIDEWALL AREA = 43 FT²

UPPER SIDEWALL

STA 1070 - 1092.6
$\text{AREA} = 2[39.5(13.5) + 16.5(13)] = 1498 \text{ IN}^2 = 11 \text{ FT}^2$

STA 1092.6 - 1109.7
$\text{AREA} = 2\left[\left(\frac{32+13}{2}\right)(17.1)\right] = 770 \text{ IN}^2 = 5 \text{ FT}^2$

STA 1109.7 - 1125
$\text{AREA} = 2\left[\left(\frac{21+39}{2}\right)(15.3)\right] = 825 \text{ IN}^2 = 6 \text{ FT}^2$

STA 1125 - 1170
$\text{AREA} = 2\left[\left(\frac{21+7}{2}\right)(45)\right] = 1{,}400 \text{ IN}^2 = 10 \text{ FT}^2$

TOTAL UPPER SIDEWALL AREA = 32 FT²

CABIN INSULATION - CONTINUED

CEILING

AREA OF 102° CYLINDRICAL SECTION WITH AVERAGE RADIUS OF 65.5"

$$AREA = 2\pi(65.5)(102\tfrac{283}{360})67 = 7{,}800\ IN^2 \cdot 54\ FT^2$$

INSULATION WEIGHT

FLOOR, FWD BLKHD & AFT BLKHD HAVE 1" OF INSULATION

FLOOR:

$WT = 86(4\ LB/FT^3)/12 = 29\ LB$

FWD BLKHD

$WT = 12(4\ LB/FT^3)/12 = 4\ LB$

AFT BLKHD

$WT = 68(4\ LB/FT^3)/12 = 23\ LB$

CEILING AND SIDEWALL HAVE 2" OF INSULATION

LOWER SIDEWALL

$WT = 43(4\ LB/FT^3)/6 = 29\ LB$

UPPER SIDEWALL

$WT = 32(4\ LB/FT^3)/6 = 21\ LB$

CEILING

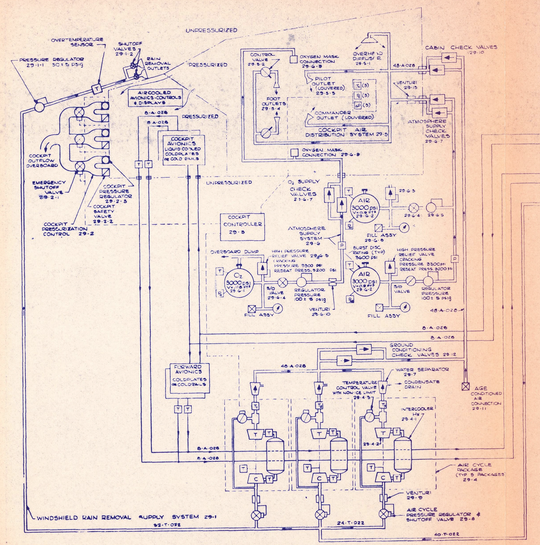
$WT = 54(4\ LB/FT^3)/6 = 36\ LB$

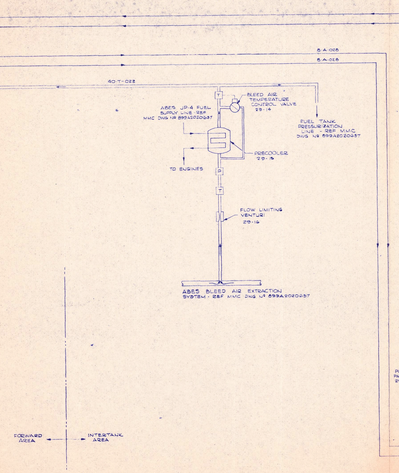
BONDING

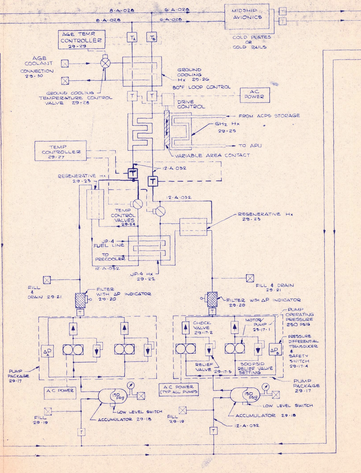
BONDING WEIGHS 0.1 LB/FT^2

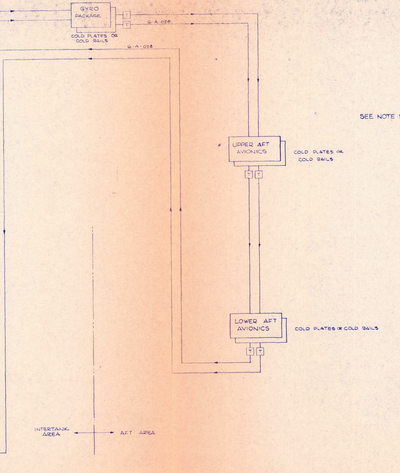
$WT = (86+12+68+43+32+54)(.1) = 30\ LB$

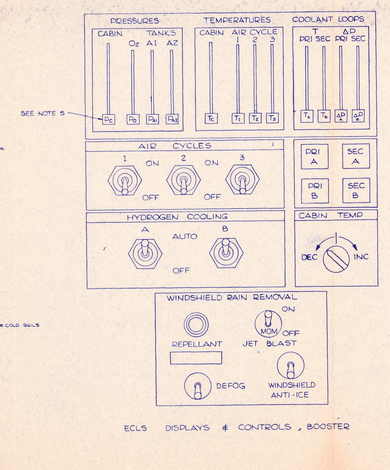
TOTAL INSULATION 172 LB











ECLS DISPLAYS & CONTROLS, BOOSTER

LEGEND:

- PRESSURE REGULATOR & SHUTOFF VALVE
- SHUTOFF VALVE, SOLENOID CONTROL
- SHUTOFF VALVE, MANUAL
- CONTROL VALVE, SOLENOID CONTROL
- CONTROL VALVE, MANUAL
- PRESSURE REGULATOR
- GAGE
- RELIEF VALVE
- CHECK VALVE
- WATER SEPARATOR
- PRESSURE REGULATOR, COCKPIT
- SAFETY VALVE, COCKPIT
- QUICK DISCONNECT
- TEMPERATURE TRANSDUCER
- PRESSURE TRANSDUCER
- VENTURI
- BURST DISC
- FILTER
- PUMP
- TURBINE
- COMPRESSOR
- ACCUMULATOR
- DIFFERENTIAL PRESSURE TRANSDUCER
- PNEUMATIC LINE
- LIQUID LINE

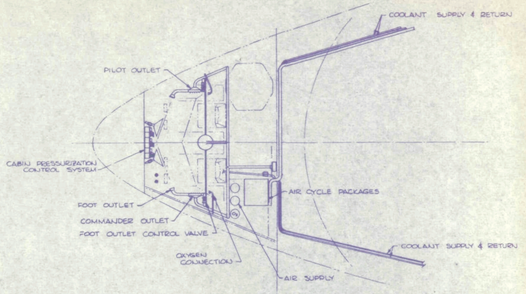
NOTES:

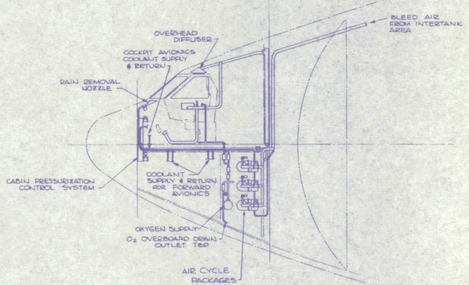
1. COMPONENT IDENTIFICATION NUMBERS ARE IDENTIFIED WITH LAST TWO DIGITS OF THIS DRAWING NUMBER 29-1, -2... ETC.
2. SYSTEM COOLANT IS FREON 21.
3. AGE COOLANT IS ETHYLENE GLYCOL.
4. PIPING CODE EXAMPLE -

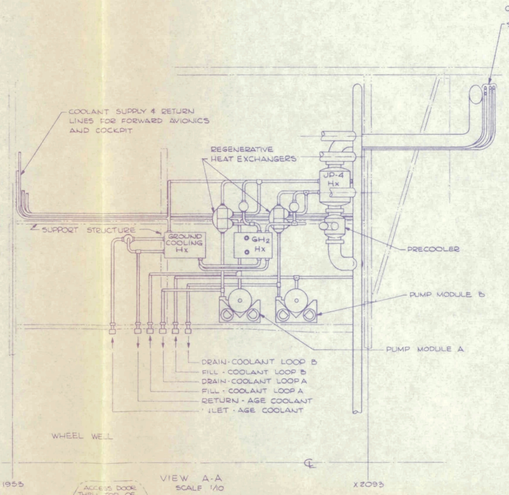
40-S-028
- WALL THICKNESS IN THOUSANDTHS OF INCH
- S = STAINLESS STEEL
- A = ALUMINUM
- T = TITANIUM
- F = INCONEL
- OUTSIDE DIAMETER IN 1/16 OF INCH

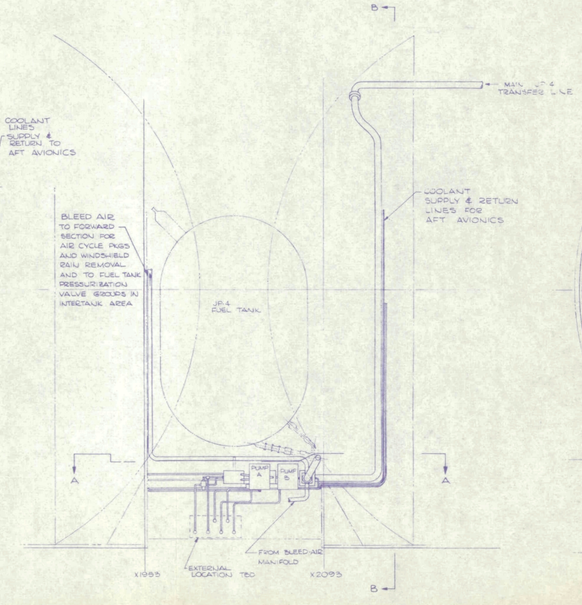
5. THE ECLS DISPLAYS ARE CODED WITH THEIR TRANSDUCERS IN THE SCHEMATIC. CABIN TEMPERATURE AND PRESSURE DISPLAYS, FOR EXAMPLE, ARE CODED T_C AND P_C AND THE TRANSDUCERS IN THE CABIN AREA OF THE SCHEMATIC ARE CODED THE SAME.
6. THIS SCHEMATIC PERTAINS TO THE BOOSTER CONFIGURATION 206

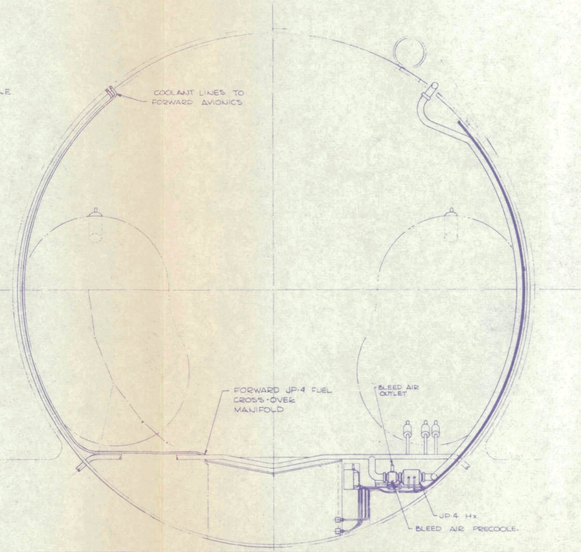
DESIGNED BY				MCDONNELL DOUGLAS ASTRONAUTICS CO.	
APPROVED BY					
CHECKED BY				SCHEMATIC COCKPIT AND AVIONICS ECLSS BOOSTER	
STRESS APPROVAL					
PROJECT ENGINEER				SIZE	CODE IDENT NO.
				B	18968
				SCALE -	SHEET 1 OF 1











ECLS INSTALLATION

18355 | 256-20-0082

PURGE SYSTEM

During the course of the purge system analysis, a trade study was conducted comparing four purge concepts. Results of the analysis are documented in Design Note IM-I-MMC-TPS-5009, Integrated Purge Concepts for the Shuttle Vehicles, 26 May 1971. At the conclusion of this trade study, a nitrogen purge ground hold system with an engine bleed re-entry and cruise back system, supplemented by a helium system was selected as a baseline system. It is this system that is documented on pages 2.14-23 through 2.14-29. The subsequent change to a dual mode ACPS,APU system(JP-4 system is now used during cruise back and the hydrogen-oxygen system is inerted) makes the cruise back purge unnecessary. The system design is being modified to reflect these changes. Details of the modified system are shown in Section 3.1.4 of MDAC Memo No. SSPI-E450-560, Airframe, Part III Booster Airframe, Section 3. However, the weight statement was left unchanged since a more detailed analysis of the cruise back requirements may reveal additional thermal control requirements to those indicated by a gross analysis. It was decided that the purge requirements of specific components or areas, that are not clearly defined at the present time, would result in a system weight close to that shown in the weight statement.

	WEIGHT-LB	PAGE NO.
PURGE SYSTEM	816	
GROUND PURGE	[348]	2.14-24
STRUCTURE	43	
VALVES	12	
PLUMBING	259	
INSTRUMENTATION	15	
CONTINGENCY 5%	19	
HELIUM FLIGHT PURGE	[362]	2.14-25
LINE	3	
VALVES	83	
DISPLAYS (CREW)	20	
FITTING, FASTENERS	10	
WIRING	24	
SUPPORTS	31	
HELIUM	19	
HELIUM CONTAINERS	155	
CONTINGENCY 5%	18	
ENGINE BLEED AIR SYS	[106] *	2.14-25
STRUCTURE	17	
PLUMBING	74	
VALVES	3	
CONTINGENCY 5%	12	

* CARRYS 137 LB JP-4 FUEL IN PROPELLANT INVENTORY

GROUND PURGE 348

STRUCTURE		(43.0)
UMBILICAL DOOR & PENALTY FOR CUTOUT		15.0
SUPPORTING STRUCTURE		28.0
VALVES		(12.0)
SHUT-OFF @ UMBILICAL 4 INCH		12.0
PLUMBING		(259.1)
UMBILICAL		6.0
MANIFOLD .040t 7IN DIA 24 IN AL		2.2
OUTLET NOZZLES - MAIN ENG COMPT (2)		2.4
SUPPLY LINES		
UMBILICAL TO BETWEEN TANKS (2) 3 7/8 DIA X .040t EPOXY FG 4554 INCH LENGTH		160.0
BETWEEN TO FWD COMPT. (2) 1 1/2 DIA X .040 t EPOXY FG		13.5
OUTLET NOZZLES - FWD COMPT (2)		1.0
INSTALLATION HARDWARE		74.0
INSTRUMENTATION		(14.8)
FLOW RATE SENSORS	(6)	6.0
PRESSURE SENSORS	(5)	5.0
WIRING		3.8

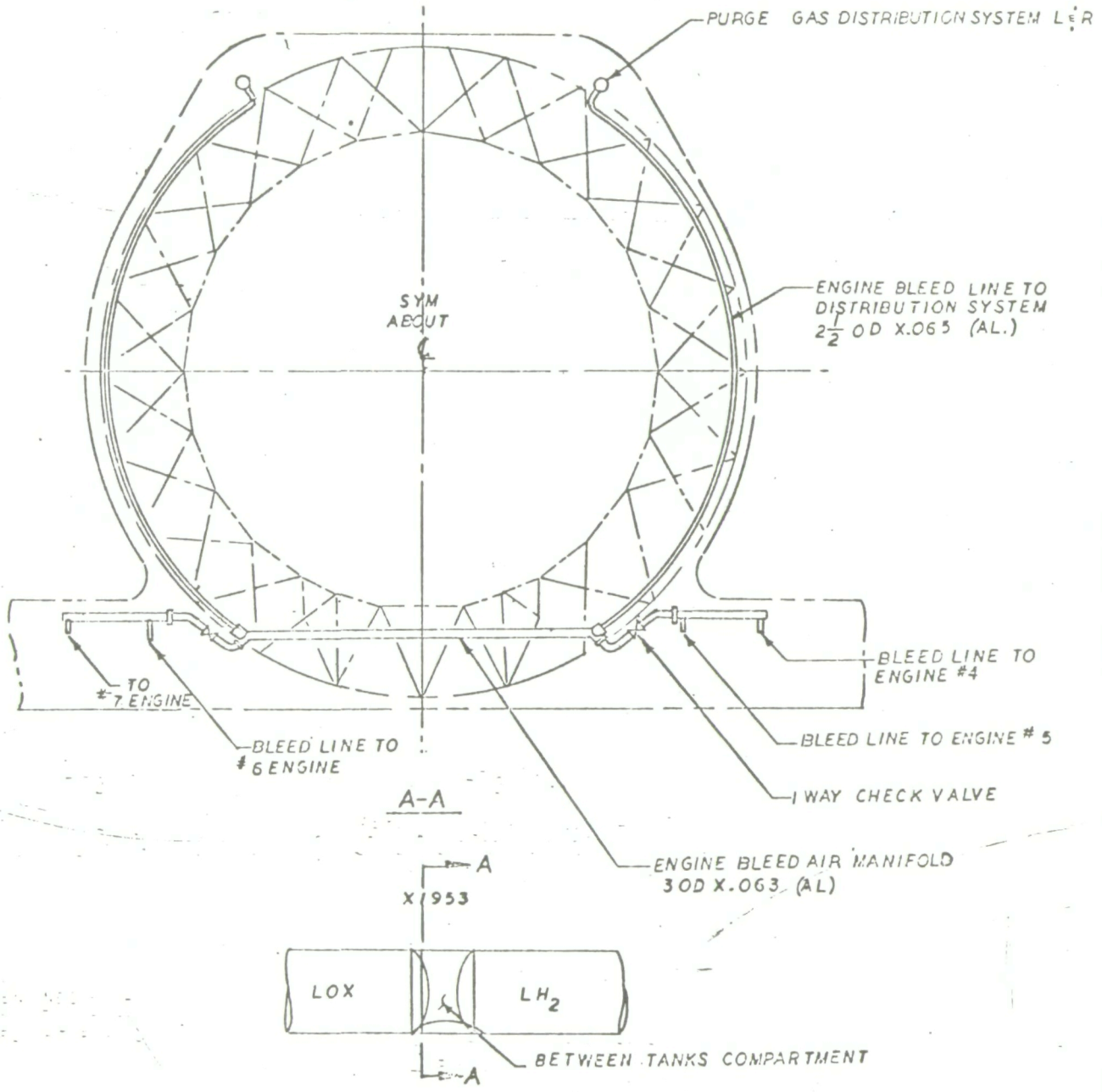
HELIUM FLIGHT PURGE 362

LINE - HELIUM SUPPLY		(3)
VALVES		(73)
FLOW CONTROL	(1)	1
CHECK ISOGRID SKINS	(24)	36
SOLENOID PIN PULLERS	(24)	36
DISPLAYS - CREW		(20)
FITTINGS, FASTENERS		(10)
WIRING		(24)
SUPPORTS		(31)
- 10%		13
- HELIUM BOTTLE		18
HELIUM		(19)
HELIUM BOTTLE	8.2#HE/#BOTTLE	(155)
CONTINGENCY	5%	(18)

ENGINE BLEED AIR SYSTEM 106

STRUCTURE		(17)
CUTOUT RE-INFORCE		12
SEALS		5
PLUMBING		(74)
SUPPLY LINES		40
MANIFOLD		29
FITTING, FASTENERS		5
VALVES		(3)
CHECK	(2)	3
FUEL - JP4	137 LB REQ.	—
CONTINGENCY	5%	(12)

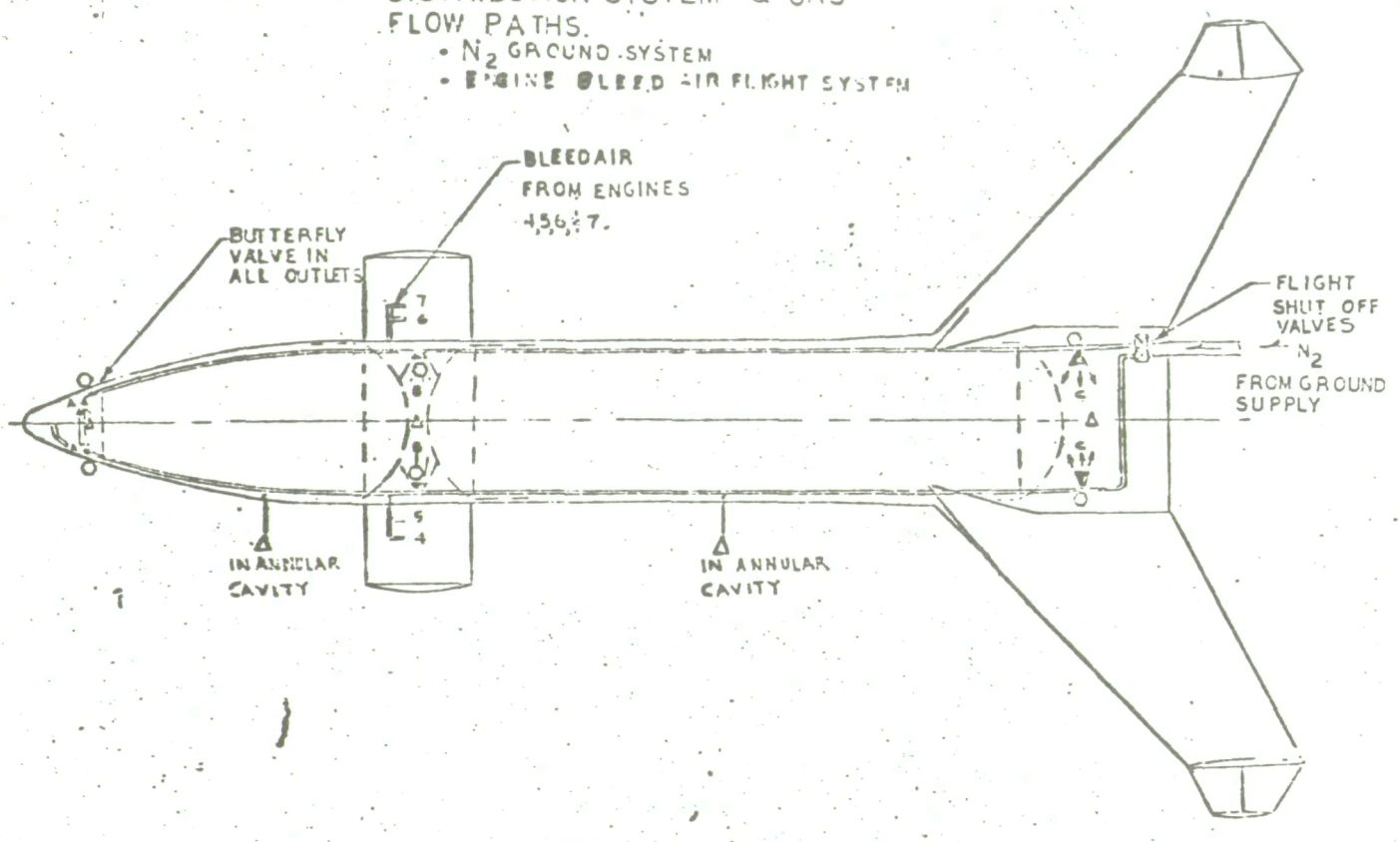
FIG. 20 BOOSTER PURGE SYSTEM
CRUISE CONFIG. USING BYPASS BLEED AIR

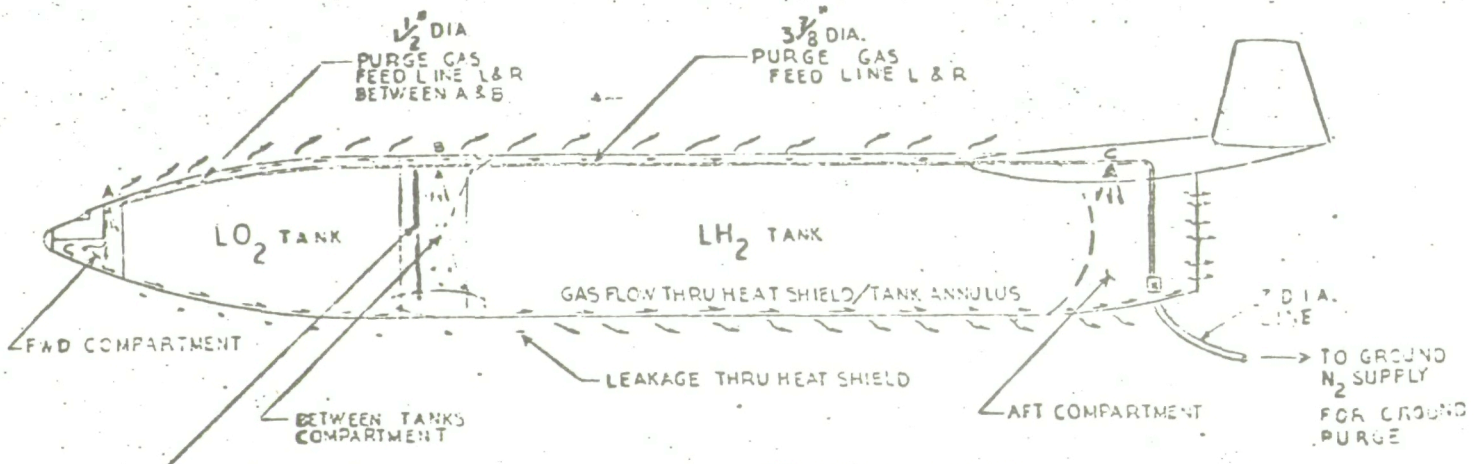


CRUISE CONFIG. USING ENGINE BY PASS BLEED AIR

SCHEMATIC OF PURGE DISTRIBUTION SYSTEM & GAS FLOW PATHS.

- N_2 GROUND SYSTEM
- ENGINE BLEED AIR FLIGHT SYSTEM

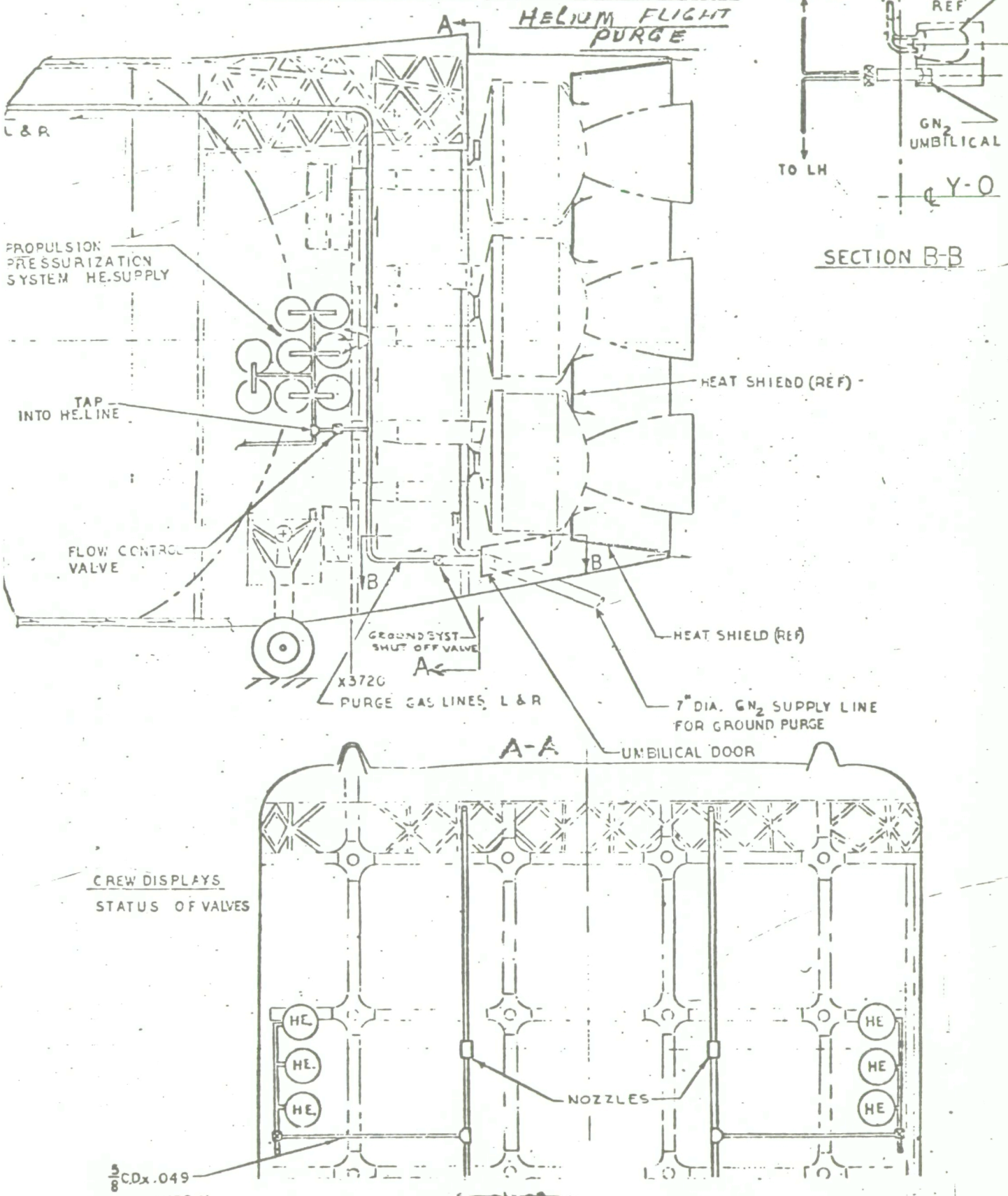


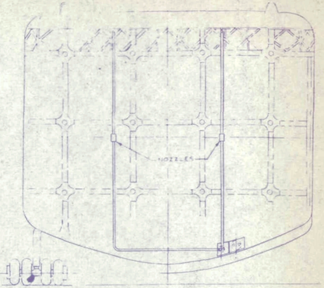


SYMBOL CODE

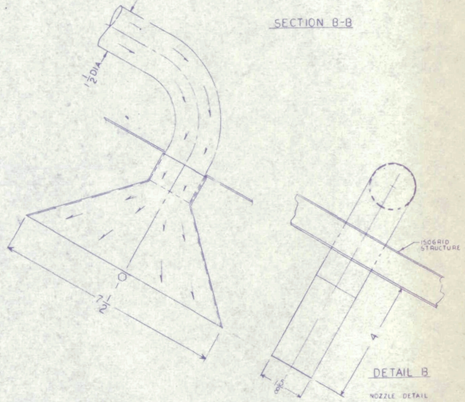
▲ = PURGE GAS NOZZLES A, B & C (6 REQD)
○ = FLOW RATE SENSORS
△ = PRESSURE SENSORS

BOOSTER PURGE SYSTEM ENTRY CONFIG.

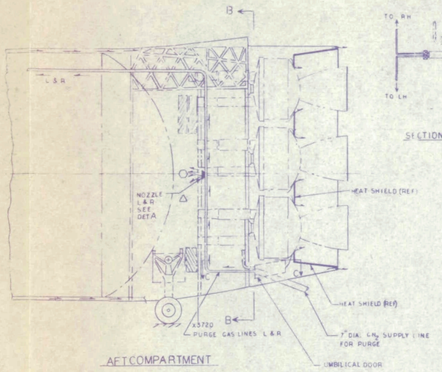




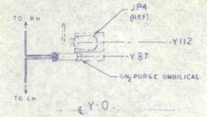
SECTION B-B



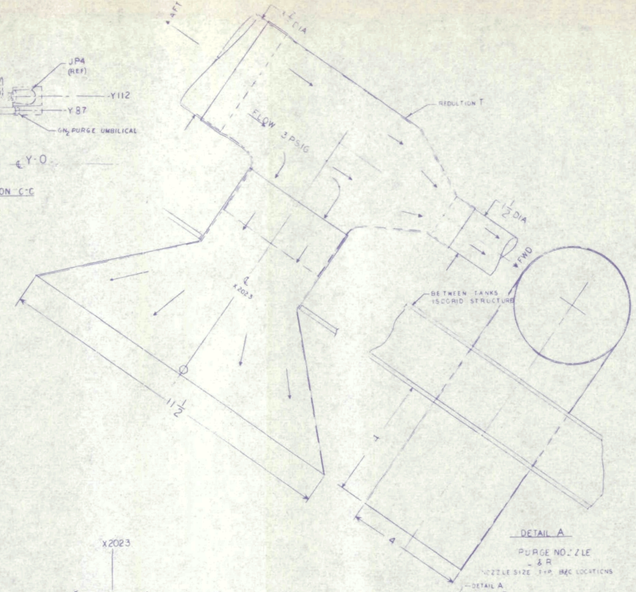
SECTION A-A



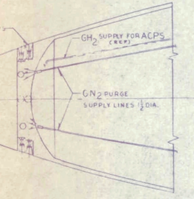
AFT COMPARTMENT



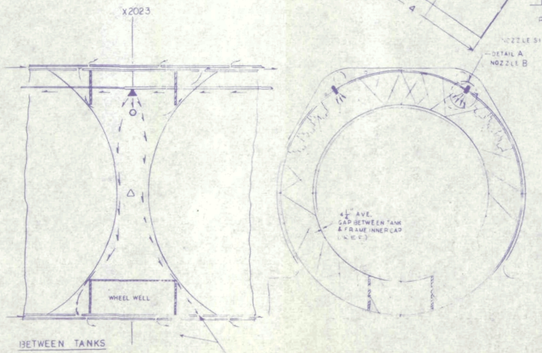
SECTION C-C



DETAIL A
PURGE NOZZLE L & R
NOZZLE SIZE TYP REC LOCATIONS
DETAIL A NOZZLE B

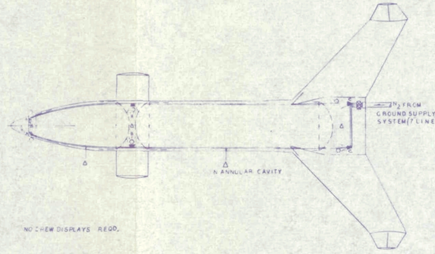


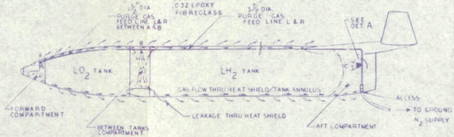
FORWARD COMPARTMENT



BETWEEN TANKS

BOOSTER PURGE SYSTEM
PRELAUNCH CONFIGURATION





SYMBOL CODE
△ = PURGE GAS NOZZLES A-B & C (P REQD)
○ = FLOW RATE SENSORS (FOR GROUND READ OUT)
△ = PRESSURE SENSORS

SCHEMATIC OF INERT GAS PURGE DISTRIBUTION SYSTEM & GAS FLOW PATHS.

APPROX VOL FT³ (UNSCLD)	OTHER USES OF PURGE	AREA	REASON FOR PURGE
490		FORWARD COMPARTMENT	POSSIBILITY OF LEAKAGE OF ACPS H_2 SYSTEM
340		LOX TANK HEAT SHIELD ANNULUS	IMPROVEMENT OF INFORMATION ON EXISTENCE OF TANK FAILURE (LOSS OF INSTRUMENTATION PLUMBING
4420		BETWEEN TANKS COMPARTMENT	SUBSTANCE TO PREVENT ACCUMULATION OF FLAMMABLE MIXTURES IN CASE OF LEAKAGE
720		LH2 TANK/HEAT SHIELD ANNULUS	POSSIBILITY OF LEAKAGE OF LH_2 OR M ADS OR MANIFOLD
1230		AFT COMPARTMENT & LH2 ISOGRID SOLID & TPD	ACCUMULATION OF FLAMMABLE MIXTURES
280		LH2 TANK ISOGRID POCKETS (BETWEEN END DOMES)	POSSIBILITY OF LEAKAGE FROM ACPS & ADS GN2 PLUMBING

MARTIN MARIETTA CORPORATION

PURGE SYSTEM CONFIG
SHUTTLE BOOSTER (BOD)

A2010 627

15. PERSONNEL PROVISIONS 288

	WEIGHT (LB)	PAGE NO.
SEATS/RESTRAINT SYSTEM	(120)	2.15-3
FIXED LIFE SUPPORT EQUIPMENT	(*)	
EMERGENCY EQUIPMENT	(29)	2.15-3
PORTABLE FIRE EXTINGUISHER	16	
HAND AX	3	
EXCAPE ROPES	10	
FURNISHING	(139)	2.15-3
INST PNL, CONSOLE, PEDESTAL	100	
GLARE SHIELD	5	
COCKPIT LIGHTING	24	
FLOOR COVERING	6	
STOWAGE, HANDHOLDS, ETC.	4	

* WEIGHT CHARGED TO EC/LS

15	PERSONNEL PROVISIONS	288
	SEATS/RESTRAINT SYS (NO = 2)	120
	FIXED LIFE SUPPORT EQUIPMENT	*
	EMERGENCY EQUIPMENT	29
	CARGO HANDLING	0
	FURNISHINGS	139

* WEIGHT CHARGED TO EC/LS

PERSONNEL PROVISIONS

		WT-LBS
SEATS & RESTRAINTS		
• ASSUME CREW SEATS TYPICAL OF AIRCRAFT EQUIV. /"GREENE"		
DC8 PILOT SEAT = 58" } USE 2@60#		120
DC10 " " = 64" }		
FIXED LIFE SUPT EQUIP.		(*
EMERGENCY EQUIPMENT		29
PORT FIREX (TYPE A-20) 2@8# =	16	
HAND AXE	3	
ESCAPE ROPES (B-70)	10	
EMERG OXYGEN SYS.	*	
FURNISHING		189

	DC10	DC8F	B70	
INSTR PNL	58	60	41	
CONSOLE	36	40	30	100
PEDESTAL	35	20	16	
	129	120	87	

GLARE SHIELD (B70)	5	
COCKPIT LIGHTING (B70)	24	
LINING & INSUL	*	
FLOOR COVERING - PAINT (B-70)	6	
STOWAGE, HANDHOLDS ETC	4	
CURRENT EST.		288#

* WT CHARGED TO ECLS

18. GROWTH/UNCERTAINTY 42,009

Booster growth/uncertainty allowance is determined by comparing the burnout weight required for each mission and payload (E0308-Space Shuttle Technical Summary, Part II-1, Section 5.1.2.3) with the estimated burnout weight for the same mission and payload. For the easterly mission the difference between these two weights is 42,009 pounds.

Percent growth/uncertainty has been defined as the ratio fo the growth/uncertainty allowance over the vehicle dry weight less cruise and ascent engines. For the easterly mission:

$$\% \text{ GR/UNC} = \frac{42{,}009}{(533{,}517 - 26{,}140 - 89{,}940)} \times 100 = 10.06$$

20. PERSONNEL 522

	WEIGHT (LB)	PAGE NO.
CREWMEN	(392)	2.20-3
GARMENTS	(13)	2.20-3
CONSTANT WEAR	4	
COVERALLS	9	
HELMET	(12)	2.20-3
PRESSURE SUITS	(26)	2.20-3
ACCESSORIES	(79)	2.20-3
HEADSETS	2	
MEDICAL & FIRST AID	5	
SURVIVAL KIT	45	
HYGENIC EQUIPMENT	3	
PERSONAL GEAR	2	
ACCESSORIES	22	

20 PERSONNEL	NO	MAN	GARMENTS	HELMET	PRESS SUIT	ACCESSORIES	522
CREW	(2)	392	13	12	26	79	522
PASSENGER	(0)						0
PERSONEL GEAR/ACCESSORIES							0
LIFE SUPPORT							0
FOOD							
EQUIPMENT – PORTABLE							

	NUMBER REQUIRED	UNIT WEIGHT	TOTAL WEIGHT
CREWMEN (90 PERCENTILE)	2	196	(392)
GARMENTS			(12.6)
CONSTANT WEAR	4	1	4.0
COVERALLS	2	4.3	8.6
HELMETS	2	6	(12)
PRESSURE SUITS	2	13	(26)
ACCESSORIES			(79.2)
HEADSETS	4	0.6	2.4
MEDICAL & FIRST AID			5.4
BIOINSTRUMENTATION	2	1.1	2.2
MEDICAL KIT	1	2.9	2.0
RADIATION DOSIMETERS	3	.4	1.2
SURVIVAL KIT			44.8
LIFE VESTS	2	2.4	4.8
SURVIVAL GEAR	1	20	20.0
LIFE RAFT	1	20	20.0
HYGENIC EQUIPMENT			2.6
BARF BAGS	2	0.1	0.2
TISSUES	1	1.4	1.4
FECAL COLLECTION BAG	2	0.2	0.4
URINE COLLECTION BAG	2	0.32	0.6
PERSONAL GEAR			2.4
SUNGLASSES	3	0.06	0.2
CHRONOMETER	2	0.13	0.2
PERSONAL PREFERENCE KIT	2	1.00	2.0
ACCESSORIES			21.6
SCISSORS	2	0.53	1.1
PENCIL	6	0.05	0.3
PENLIGHT	3	0.34	1.0
UTILITY KIT	2	2.00	4.0
FLIGHT DATA FILE	1	10.00	10.0
BINOCULARS	1	1.20	1.2
PORTABLE FLOODLIGHT	1	4.00	4.0

REF: NASA LETTER, MSC, CF31-71L-02

23. RESIDUAL & UNEXPENDABLE FLUIDS [14707]

	WEIGHT (LB)	PAGE NO.
ASCENT	(4796)	2.23-4
TANK AND LINES GH_2	741	
TANK AND LINES GO_2	4055	
CRUISE	(4045)	2.23-4
TANK JP-4	2620	
LINES JP-4	1425	
ATTITUDE CONTROL	(306)	2.23-4
TANK LO_2	21	
TANK LH_2	5	
PRESSURANT - TANK GO_2	10	
PRESSURANT - TANK GH_2	11	
ACCUMULATOR & LINES O_2	213	
ACCUMULATOR & LINES H_2	46	
ENVIRONMENTAL CONTROL SYSTEM	(84)	2.23-4
ATMOSPHERE AIR	28	
ATMOSPHERE O_2	2	
FREON	54	
PRIME POWER "APU"	(55)	2.23-4
TANK LH_2	4	
CRUISE TANK JP-4	39	
TANK LO_2	3	
PRESSURANT - TANK GH_2	8	
PRESSURANT - TANK GO_2	1	
HYDRAULIC	(5381)	2.23-5
POWER GENERATION	3308	
TVC SYSTEM	778	
ELEVON ACTUATION	829	
RUDDER ACTUATION	232	
JET FLAP ACTUATION	39	
ASCENT ENGINE CONTROL SYSTEM	16	
LANDING SYSTEM (STEERING, BRAKING, GEAR & DOOR ACTUATION)	179	

23. RESIDUAL & UNEXPENDABLE FLUIDS (CONTINUED)

MISCELLANEOUS	(40)	2.23-5
SERVICE PRESSURANT GH_2	6	
SERVICE PRESSURANT GO_2	1	
SERVICE FUEL LH_2	3	
SERVICE OXIDIZER LO_2	3	
PNEUMATIC SYSTEM HELIUM	27	

23. RESIDUAL & UNUSABLE FLUIDS	14707
ASCENT	4796
CRUISE	4045
MANEUVER	0
ATTITUDE CONTROL	306
ECS	84
APU	55
HYDRAULIC	5381
MISCELLANEOUS	40

RESIDUAL AND UNEXPENDABLE FLUIDS | 14707 |

ASCENT (REF: SSPI-E450-577, SECTION 4.1.11) (4796)

TANK AND LINES - GH_2 (741 LBS) AND GO_2 (4066 LBS)

The main propulsion pressurant masses at landing are based on a pressure of 18 psia (middle of required 17-19 psia band). The oxygen tank gas temperature at landing is assumed to be ambient (520°R). The hydrogen tank gas temperature lags the external temperature by approximately 5 minutes (due to tank insulation). Therefore the hydrogen gas temperature at landing is 500°R.

CRUISE PROPULSION (SSPI-E450-579, SECTION 4.1.3) (4045)

The residual propellant in the tank is equal to 2% of the total propellant less residuals. An additional 1425 lbs is trapped in the lines.

ATTITUDE CONTROL (REF: SSPI-E450-578) (306)

The residual propellant in the tank is equal to 2% of the usable propellant weight. The pressurant and accumulator residuals were calculated as a function of volume.

ENVIRONMENTAL CONTROL (SEE PAGE 2.14-17) (84)

PRIME POWER "APU" (REF: SSPI-E450-593) (55)

The residual propellant in the tank is equal to 2% of the usable propellant weight.

HYDRAULIC (5381)

Hydraulic Fluids are calculated in Section 2.11 with the exception of 8 lbs of fluid added for landing gear door actuation (DC-10 value).

MISCELLANEOUS (40)

SERVICE PROPELLANT
(REF: SSPI-E450-578, Section 4 and SSPI-E450-593, Section 4)

Residual propellant is 2% of the service propellant weight.

PNEUMATIC SYSTEM HELIUM (27 LBS)
(REF: SSPI-E450-577, Section 4.1.10)

It is possible that the helium requirements will be revised.

25. RESERVE FLUIDS 10245

	WEIGHT (LB)	PAGE NO.
CRUISE JP-4	(10000)	2.25-3
ATTITUDE CONTROL	(54)	2.25-3
LO_2	48	
LH_2	6	
PRIME POWER "APU"	(191)	2.25-3
LO_2	3	
LH_2	14	
JP-4	174	

25. RESERVE FLUIDS	10245
ASCENT	0
CRUISE	10 000
MANEUVER	0
ATTITUDE CONTROL	54
ECS	0
APU	191
HYDRAULIC	0

RESERVE FLUIDS — 10245 LB

CRUISE JP-4 (10 000)

ALLOWANCE FOR ONE "GO AROUND" MANEUVER IS PROVIDED. (REF: SSPI-E450-579, SECTION 4.1.3)

ATTITUDE CONTROL (54)

A 5% RESERVE IS PROVIDED FOR THE ATTITUDE CONTROL PROPELLANT. SINCE THE ACS CRYOGENIC PROPELLANTS AND THE APU CRYOGENIC PROPELLANTS SHARE A COMMON TANK, THE 5% ACS RESERVE AND THE 10% APU RESERVES ARE CALCULATED ON A ROOT SUM SQUARED BASIS. (REF. SSPI-E450-578, SECTION 4.)

PRIME POWER "APU" (191)

THE JP-4 RESERVE PROPELLANT IS 10% OF THE USABLE JP-4 APU PROPELLANT. THE CRYOGENIC APU RESERVE PROPELLANTS ARE DISCUSSED IN THE ATTITUDE CONTROL PARAGRAPH ABOVE. (REF: SSPI-E450-593, SECTION 4)

26. INFLIGHT LOSSES & APU PROPELLANT [22847]

	WEIGHT (LB)	PAGE NO.
ASCENT	(20320)	2.26-3
PRESSURANT - GH_2	526	
PRESSURANT - GO_2	366	
TANK RESIDUAL - LH_2	1000	
TANK RESIDUAL - LO_2	1700	
LINE RESIDUAL - LH_2	115	
LINE RESIDUAL - LO_2	1900	
ENGINE RESIDUAL - LH_2	480	
ENGINE RESIDUAL - LO_2	8160	
PU BIAS - LH_2	4841	
CHILLDOWN PROPELLANT - LH_2	20	
CHILLDOWN PROPELLANT - LO_2	360	
SHUTDOWN LOSS - LH_2	324	
SHUTDOWN LOSS - LO_2	528	
ATTITUDE CONTROL	(9)	2.26-4
ACPS PUMP COOLANT - LH_2	5	
ACPS PUMP COOLANT - LO_2	4	
MISCELLANEOUS	(483)	2.26-5
SERVICE PROPELLANT - LH_2	139	
SERVICE PROPELLANT - LO_2	139	
PURGE SYSTEM PENALTY JP-4	137	
PNEUMATIC SYSTEM HELIUM	68	
USABLE APU PROPELLANT	(2035)	2.26-5
LH_2	168	
LO_2	126	
JP-4	1741	

26. INFLIGHT LOSSES & APU PROPELLANT	22847
ASCENT	20320
CRUISE	0
MANEUVER	0
ATTITUDE CONTROL	9
ECS	0
APU	2035
HYDRAULIC	0
MISCELLANEOUS	483

INFLIGHT LOSSES AND APU PROPELLANT 22,847

ASCENT PROPULSION (REF: SSPI-E450-577, SECTION 4.1.11) (20,320)

PRESSURANT - GH_2 (526 LBS) AND GO_2 (366 LBS)

The inflight loss pressurant consists of the pressurant vented between main engine thrust decay and landing. The pressurant at landing is a residual and is discussed in Section 2.23. The total main propulsion pressurant masses at the end of main engine thrust decay were determined from the ullage conditions at engine cutoff. These conditions include the effects of mixing warm engine bleed and cold prepressurization gases as well as pressurant collapse. For hydrogen, the pressure and temperature are 25 psia and 405°R, respectively. For oxygen the pressure and temperature are 18 psia and 475°R, respectively. The oxygen and hydrogen pressurant added during burn is the difference between the total pressurant masses at cutoff and the prepressurization masses.

TANK RESIDUAL - LH_2 (1000 LBS) AND LO_2 (1700 LBS)

The tank pull-through mass is determined from considerations of tank geometry and fluid dynamics (see pull-through section).

LINE RESIDUAL - LH_2 (115 LBS) AND LO_2 (1900 LBS)

The propellant trapped in the feedlines consists of the sum of the liquids remaining in the other feedlines at the end of thrust decay when the liquid level in the first feedline to deplete reaches the engine interface.

ENGINE RESIDUAL - LH_2 (480 LBS) AND LO_2 (8160 LBS)

The main engine trapped propellants, thrust level, flowrates, cutoff consumption, and cutoff mixture ratio (O/F = 5.1) were obtained from the engine ICD, 13M15000B, dated March 12, 1971.

PU BIAS - LH_2 (4841 LBS)

The PU bias is 0.156% of the total nominal main-stage propellant burned by the engines and is added to minimize residuals.

CHILLDOWN PROPELLANT - LH_2 (20 LBS) AND LO_2 (360 LBS)

The propellants trapped in the chilldown lines consists of the total mass of propellants which are in these lines. This mass cannot be burned by the main engines. (See page 2.6-15.)

SHUTDOWN LOSS - LH_2 (324 LBS) AND LO_2 (528 LBS)

The shutdown loss consists of additional propellant which must be loaded to account for actual cutoff performance. The trajectory program considers that the cutoff impulse is generated at the steady state Isp. The actual Isp during cutoff is less than the steady-state value. Therefore, the actual propellant mass consumed in generating the cutoff impulse is greater than the mass required in the trajectory program. The shutdown loss is computed by subtracting the cutoff consumption used in the trajectory ($M_{c/o} = I_{c/o}/I_{sp\ ss}$) at EMR = 6:1 from the actual cutoff consumption given in the ICD at EMR = 5:1.

ATTITUDE CONTROL (REF: SSPI-E450-578, SECTION 4) (9)

ACTS PUMP COOLANT - LH_2 (5 LBS) AND LO_2 (4 LBS)

Pump cooling propellant based on analysis of the required cooling.

MISCELLANEOUS (483)

SERVICE PROPELLANT - LH_2 (139 LBS) AND LO_2 (139 LBS)

Hydrogen service propellant based on 16.5% of usable plus reserve of ACPS and APU. Oxygen service propellant based on 3.3% of usable plus reserves of ACPS and APU.

PURGE SYSTEM PENALTY JP-4 (137 LBS)

JP-4 is calculated for off mixture ratio of cruise engines when air is bled off for purge requirements.

PNEUMATIC SYSTEM HELIUM (68 LBS)
(REF: SSPI-E450-577, SECTION 4.1.10)

It is possible that the helium requirements will be revised.

USABLE APU PROPELLANT (REF: SSPI-E450-593) (2035)

The APU usable propellants (LH_2/LO_2 and JP-4) was calculated based on the Booster power requirements.

2.27 Propellant - Ascent

3 038 600

The 3,038,600 lb. of usable ascent propellant is the same for all missions. The usable propellant weight requirement is based on achieving the missions with nominal specific impulse. The usable propellant load for achieving the missions with minimum specific impulse is 3,085,081 lb.

The propellant mixture ratio (oxidizer:fuel) is 6:1 resulting in 2,604,515 lb. of LO_2 and 434,085 lb. of LH_2.

This weight does not include ascent propellants charged to residuals and inflight losses.

Propellant densities are based on saturation conditions at 15.2 psia for oxygen and 16.2 psia for hydrogen. These densities are 71.00 lb/ft^3 and 4.395 lb/ft^3 for oxygen and hydrogen, respectively.

2.28 Propellant - Cruise

121 000*

Shown below are the usable cruise propellant (JP-4) weights. These weights do not include the 10,000 lb. go-around allowance charged to reserves or the line residuals (1425 lb.) or the tank residual which is equal to 2% of the total cruise propellant less residuals.

The allowance for head winds and an engine out is dumped prior to landing if it is not required.

Easterly (Baseline) Mission (Range = 454 n.m.)	
Nominal (No Wind)	97,000
Dumped Allowance	34,000
Total	131,000
Less Reserve	-10,000
Total Usable	121,000 lb.
Resupply Mission (Range = 453 n.m.)	
Nominal (No Wind)	97,000
Dumped Allowance	27,000
Total	124,000
Less Reserve	-10,000
Total Usable	114,000 lb.
Polar Mission (Range = 442 n.m.)	
Nominal (No Wind)	91,000
Dumped Allowance	11,000
Total	102,000
Less Reserve	-10,000
Total Usable	92,000 lb.

*Total Usable Baseline Mission

Ref. Booster Technical Summary, MDC E0308, Vol. III, Part II-3, Section 3.1.5.23

29. PROPELLANT - ATTITUDE CONTROL SYSTEM 1212

The 1212 lb of usable ACS propellant is composed of 991 lb of LO_2 and 221 lb of LH_2. The aforementioned weights do not include ACS propellants charged to in-flight losses, reserves or residuals.

There is no maneuver requirement for this system.

Thrusters: 16
Thrust (VAC): 1600 lb
Specific Impulse-Steady: 379 sec
Specific Impulse-Pulse: 360 sec

APPENDIX A

MAIN LANDING GEAR CALCULATED WEIGHT ANALYSIS

MAIN LANDING GEAR WEIGHT COMPARISON
PARAMETRIC DERIVATION VERSUS PRELIMINARY CALCULATED WEIGHT

LBS/VEHICLE

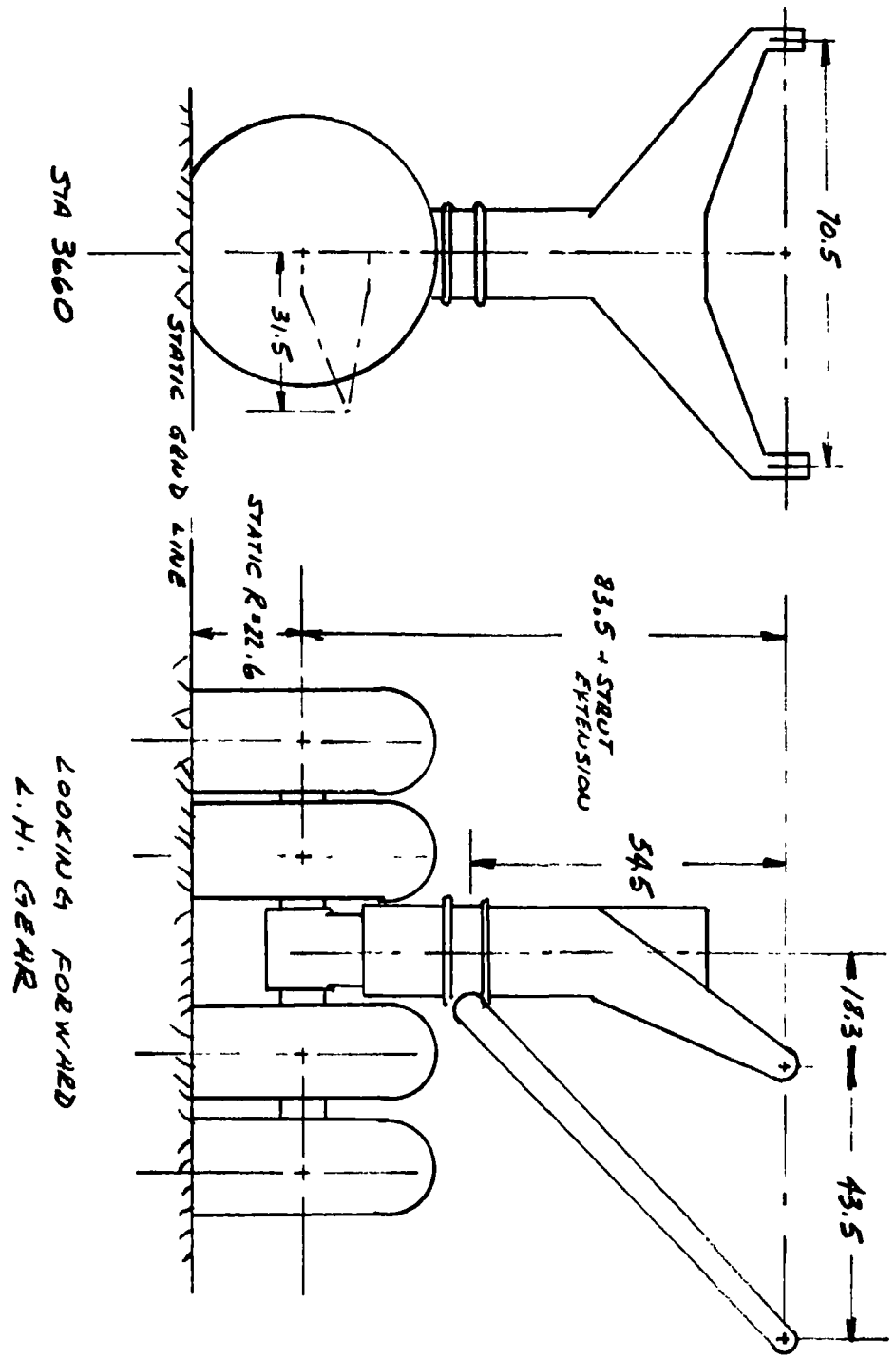
DESCRIPTION	PARAMETRIC DERIVATION	CALCULATED WEIGHT
CYLINDER	1200.	1200.
PISTON	770.	990.
INTERNAL PARTS	470.	366.
TORQUE LINKS & PINS	390.	419.
AXLE, AXLE NUT & MISC ATTACH	640.	696.
LOWER & UPPER SIDE BRACE & ATTACH	690.	762.
FIXED BRACE	250.	◇
TRUNNION PINS	⬡	205.
SYSTEMS	1050.	1050. X
ATTACH STRUCTURE	2840.	2840. X
ROLLING ASSY	5760.	5760. X
	15,000.	15,388.

⬡ INCLUDED IN ATTACH STRUCTURE WEIGHT
X USED SAME WEIGHT AS PARAMETRIC DERIVATION
◇ INCLUDED IN ATTACH STRUCTURE WEIGHT

CONCLUSIONS:

THE ABOVE TABLE SHOWS THAT THE PARAMETRIC METHOD USED FOR THE MAIN GEAR DIFFERS FROM THE CALCULATED METHOD IN APPENDIX A (PAGE 2.5-94) BY LESS THAN 1.5%. IT IS EXPECTED THAT SIMILAR AGREEMENT COULD BE ACHEIVED FOR THE NOSE GEAR.

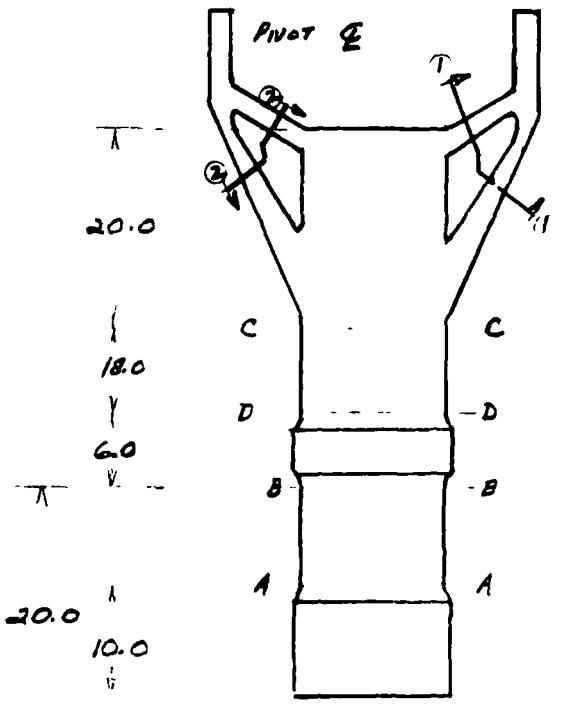
MAIN LANDING GEAR



MAIN LANDING GEAR PRELIMINARY CALCULATED WEIGHT SUMMARY

PART DESCRIPTION	LBS./STRUT
SHOCK STRUT ASSY	
CYLINDER	1100.0
PISTON	495.0
INTERNAL PARTS	(183.0)
ORIFICE TUBE, RETAINER & PLATE	17.1
METERING PIN ASSY	7.8
BOTTOM SPACER	39.2
UPPER BEARING, RINGS & PACKING	18.2
LOWER BEARING & PACKING	12.1
LOWER NUT	6.8
MISC PARTS	15.8
SHOCK STRUT FLUID	66.0
AXLE, AXLE NUT, & MISC AXLE ATTACH	347.7
SIDE BRACE & ATTACH PINS	381.0
TRUNNION PINS & BOLTS	102.5
TORQUE LINKS & BOLTS	209.4

MAIN GEAR SHOCK STRUT CYLINDER



SECTION DIMENSIONS

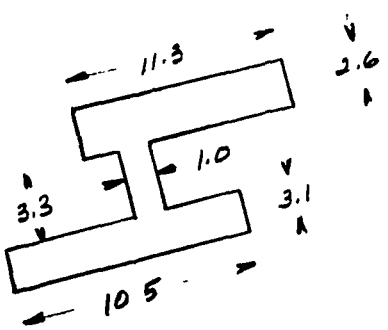
A-A	12.06	OD	11.4	I.D
B-B	12.34	OD	11.4	I.D.
C C	13.10	OD	11.4	I.D
D D	12.56	OD	11.4	I D

1-1 65.3 IN²

2-2 52.4 IN²

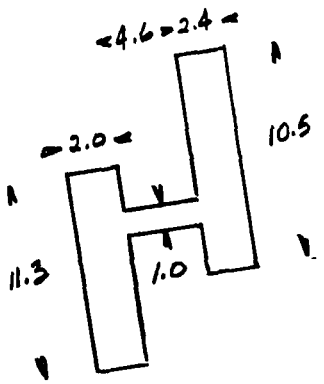
MATERIAL

300M ; .283 LBS/IN³



SECTION ① ①

10.5 × 3.1 = 32.6
1.0 × 3.3 = 3.3
11.3 × 2.6 = 29.4
65.3 IN²



SECTION ② ②

10.5 × 2.4 = 25.2
4.6 × 1.0 = 4.6
11.3 × 2.0 = 22.6
52.4 IN²

CYLINDER CALCULATION

- BOTTOM OF CYLINDER TO SECTION A-A

OD = 12.06 ID = 11.40

$(12.06^2 - 11.40^2) \cdot .785 \cdot 10.0''$ = 118.0 in³

- TORQUE LINK LUG

OD = 13.0 ID = 12.06

$(13.00^2 - 12.06^2) \cdot .785 \cdot 9.0$ = 170.0 in³

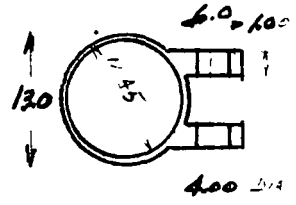
$(4.0^2 - 3.0^2) \cdot .785 \cdot 10.0$ = 31.3 in³

- SECTION A-A TO SECTION BB

OD = 12.06 ⇒ 12.34 ID = 11.40

$((12.06^2 + 12.06 \cdot 12.34 + 12.34^2)/3 - 11.4^2) \cdot .785 \cdot 10.0$ = 145.2 in³

- SIDE BRACE ATTACH LUG



OD = 13.0 ID = 12.45

$(13.00^2 - 12.45^2) \cdot .785 \cdot 6.0$ 66.0 in³

$(6.0 \cdot 7.0 - 4.0^2 \cdot .785) \cdot 2.0$ = 58.5 in³

- SECTION B-B TO SECTION D-D

$OD_{BB} = 12.34$ $OD_{DD} = 12.56$ $ID_{BD} = 11.4$

$((12.34^2 + 12.34 \times 12.56 + 12.56^2)/3 - 11.40^2) \cdot .785 \times 6.0$ = 117.5 in³

- SECTION DD TO SECTION C-C

$OD_{DD} = 12.56$ $OD_{CC} = 13.10$ $ID_{C} = 11.40$

$((12.56^2 + 12.56 \times 13.10 + 13.10^2)/3 - 11.4^2) \cdot .785 \times 18.0$ = 480 in³

CYLINDER CALCULATION CON'T

· SECTION C-C TO TOP OF CYLINDER

$OD_{cc} = 13.10$ $ID_{cc} = 11.40$

$13.10^2 - 11.40^2 \cdot .785 \times 20.0 = 660.0 \text{ in}^3$

PIVOT ARM, SECTIONS ① ① & ② ②

AREA ① ① = 65.3 L = 34.5

$65.3 \times 34.5 \times .50 = 1130.0 \text{ in}^3$

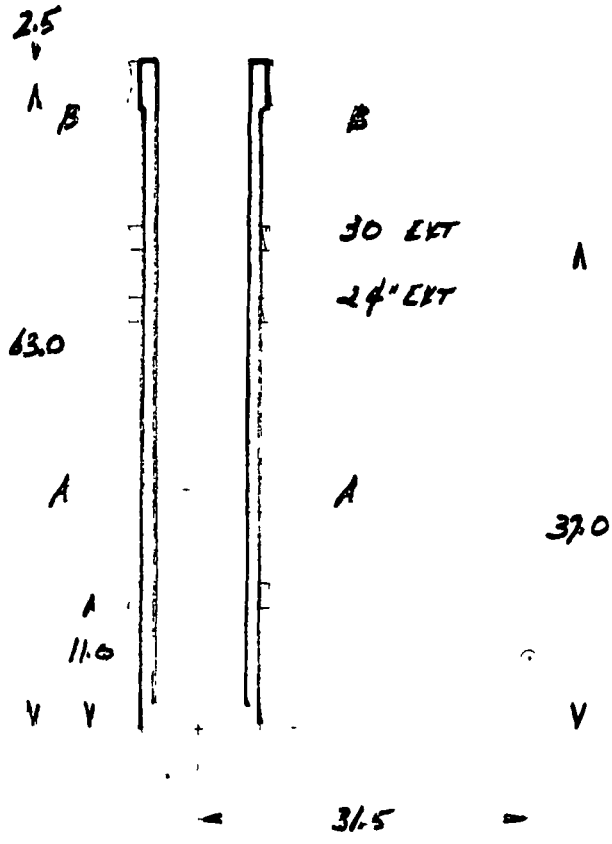
AREA ② ② = 52.4 L = 345

$52.4 \times 34.5 \times .50 = 9050 \text{ in}^3$

TOTAL VOL CYLINDER 3881.5 in^3

$3881.5 \text{ in}^3 \times .283 \#/\text{in}^3 = 1100.0 \text{ LBS/CYLINDER}$

MAIN GEAR SHOCK STRUT PISTON



SECTION DIMENSIONS

AA	10.0" OD	8.75" ID
BB	9.21" OD	8.75" ID

ASSUME ½ VOLUME IS CONTAINED IN LUG

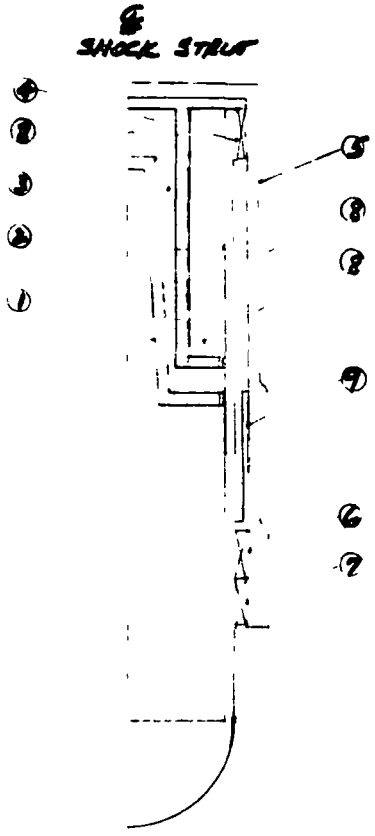
MATERIAL
300 M STEEL
.283 LBS/IN³

CALCULATION

$(9.21^2 - 8.75^2) \cdot 785 \times 28.5$	= 190.0
$(10.00^2 - 8.75^2) \cdot 785 \times 37.0$	682.0
LUG END	872.0
	1744.0 IN³

$1744.0\ in^3 \times .283\ LBS/in^3 = 495.0\ LBS/PISTON$

MAIN GEAR SHOCK STRUT INTERNAL PARTS



LEGEND

1. METERING PIN ASSY
2. ORIFICE TUBE ASSY
3. SHOCK STRUT PISTON
4. UPPER BEARING SEALS & RINGS
5. OUTER CYLINDER
6. LOWER BEARING & SEALS
7. LOWER NUT
8. SHOCK STRUT OIL
9. SPACER

DIMENSIONS

STROKE	30.0
CYLINDER ID	11.4
PISTON OD	8.75
ORIFICE TUBE ~ l	31.0
METERING PIN ~ l	31.0
D/t	35.0
SPACER ~ l	22.0
UPPER BEARING ~ l	5.0
LOWER BEARING ~ l	5.0
LOWER NUT ~ l	1.0

CALCULATIONS

- ORIFICE TUBE, RETAINER & PLATE ~ MAT'L ALUM
  60" OD, D/t = 35, t = 60/35 = .172, then 5.656 ID

  $(6.000^2 - 5.656^2) \cdot 785 \times 31.0 = 97.5$
  $11.4^2 \cdot 785 \times .50 = 51.0$
  $(8.75^2 - 5.656^2) \cdot 785 \times .50 = 17.5$
  $166.0 \times .103\ \#/in^3 = 17.1$ LBS

- METERING PIN ASSY ~ MAT'L ALUM
  4.0 OD, D/t = 35, t = 4.0/35 = .115 then ID = 3.77

  $(4.00^2 - 3.77^2) \cdot 785 \times 31.0 = 44.0$
  $(8.75^2 - 3.77^2) \cdot 785 \times .50 = 29.8$
  $4.0^2 \cdot 785 \times .50 = 6.3$
  $75.1 \times .103\ \#/in^3 = 7.8$ LBS

CALCULATIONS (CON'T)

- SPACER ~ ALUM
  11.40 OD, D/t = 35 then t = 11.4/35 = .335
  $(11.40^2 - 10.73^2) \cdot 785 \times 22.0 \times .103$ LBS/IN³ = 39.2 LBS

- UPPER BEARINGS, RINGS, PACKING
  11.40 OD 9.21 ID
  $(11.40^2 - 9.21^2) \cdot 785 \times 5.0 \times .103$ LBS/IN³ = 18.2 LBS

- LOWER BEARINGS, PACKING
  11.40 OD 10.00 ID
  $(11.40^2 - 10.00^2) \cdot 785 \times 5.0 \times .103$ LBS/IN³ = 12.1 LBS

- LOWER NUT ~ STEEL
  11.40 OD 10.00 ID
  $(11.40^2 - 10.00^2) \cdot 785 \times 1.0 \times .283$ LBS/IN³ = 6.8 LBS

- MISC PARTS ~ USE 10% OF ABOVE TOTAL = 10.0 LBS
- 5% CONTINGENCY 5.8 LBS

TOTAL – INTERNAL PARTS 117.0 LBS/STRUT

OIL CALCULATION

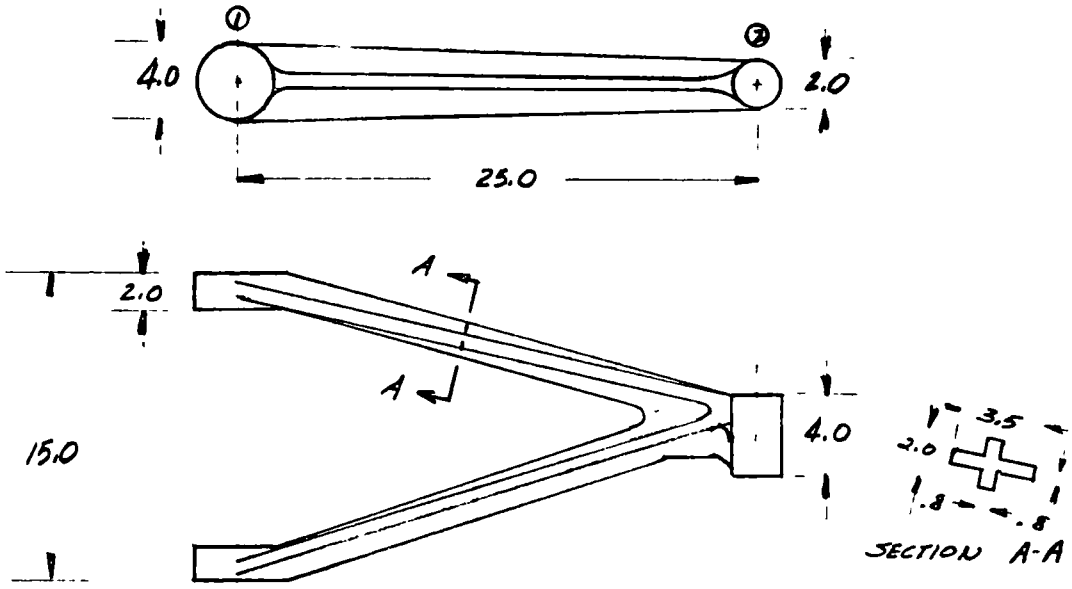
- BETWEEN PISTON & ORIFICE TUBE
  $(8.75^2 - 6.00^2) \cdot 785 \times 30.0 = 942$ in³
- BETWEEN ORIFICE TUBE & METER PIN
  $(5.656^2 - 4.00^2) \cdot 785 \times 30.0 = 377$ in³
- BETWEEN OUTER CYLINDER & PISTON
  $(11.40^2 - 10.00^2) \cdot 785 \times 30.0 = 705$ in³

3024 in³

OIL WEIGHT = 3024 in³ ÷ 231 in³/GAL · 7.5 LB/GAL = 66 LBS/STRUT

MAIN GEAR TORQUE LINKS

TOP AND BOTTOM TORQUE LINKS ARE IDENTICAL



MAT'L 300M STEEL @ .283 LBS/IN³

AREA = .8 (3.5) + .8 (1.2) = 2.8 + .96 = 3.76 in²

ASSUME ⅓ VOLUME IN END FITTINGS

$$3.76\ in^2 \times 25.0\ in \times 2 \times \tfrac{3}{2}\left(.283\ LBS/in^3\right) = 79.5\ LBS.$$

ATTACH POINT ① ~ 2 REQ'D PER STRUT

OD = 3.0 D/t = 5.0 t = 3.0/5.0 = .60 ID = 1.8

MAT'L 300 M @ .283 LB/in³

$$(3.0^2 - 1.8^2) \cdot .785 \times 15.0 \times 2 \times .283 = 47.6\ LBS$$

ATTACH POINT ② ~ 1 REQ'D PER STRUT

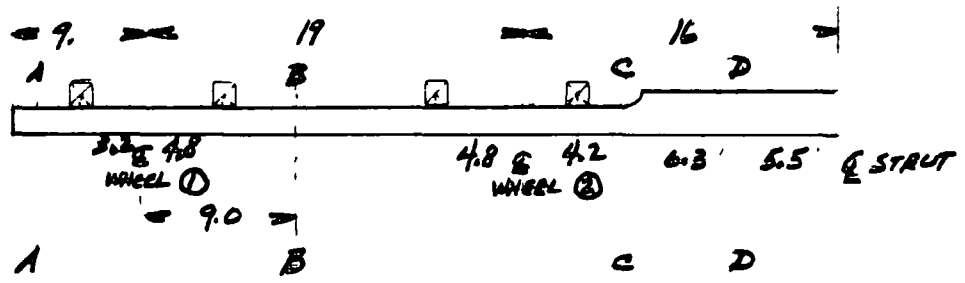
OD = 1.625, D/t = 5 t = 1.625/5.0 = .325 ID ≅ 1.00

MAT'L = 300 M @ .283 LBS/in³

$$(1.625^2 - 1.000^2) \cdot .785 \times 4.0 \times .283 = 2.8\ LBS$$

209.4 LBS/STRUT

MAIN GEAR SHOCK STRUT AXLE



SECTION DIMENSIONS

AA	6.5	OD	5.85	ID
BB	6.5	OD	5.85	ID
CC	6.5	OD	4.34	ID
DD	7.0	OD	4.34	ID

MATERIAL

300M STEEL
.283 LBS/IN³

CALCULATION

A-B $(6.5^2 - 5.85^2) \cdot .785 \times 18.0 = 113.0$

B-C $\left(6.5^2 - (5.85^2 + 5.85 \cdot 4.34 + 4.34^2) \cdot \tfrac{1}{3}\right) \cdot .785 \times 14.2 = 180.0$

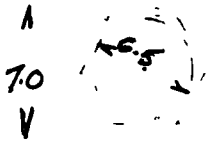
C-D $(7.0^2 - 4.34^2) \cdot .785 \times 11.8 = 280.0$

VOLUME OF AXLE HALF 573.0 in^3

$573.0 \text{ in}^3 \times 2 \times .283 \text{ LBS/in}^3 = 324 \text{ LBS/AXLE/STRUT}$

WHEEL NUT

MAT'L 300M STEEL
OD = 7.0 ID = 6.5 ℓ = 3.0 ; 4 REQ'D PER AXLE

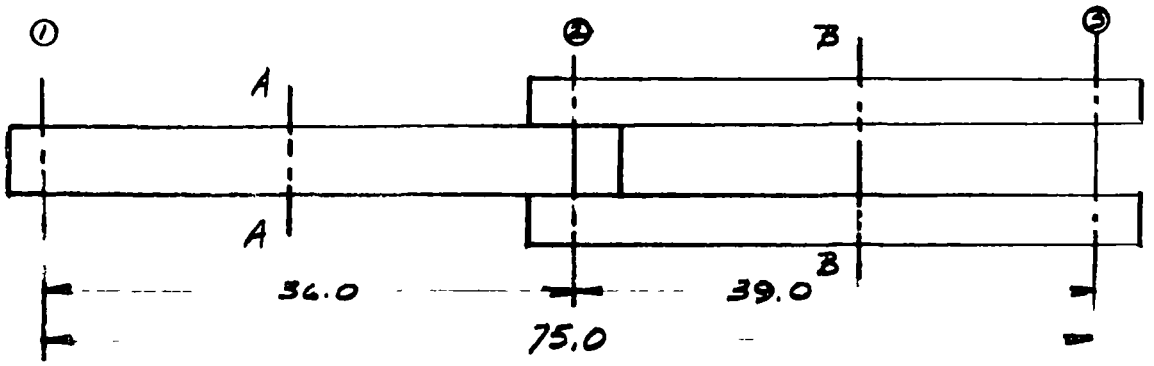


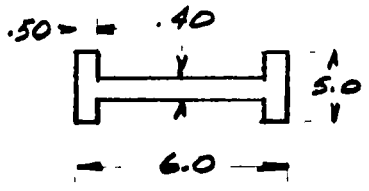
$(7.0^2 - 6.5^2) \cdot .785 \cdot 3.0 \cdot 4 \cdot .283 \#/\text{in}^3 = 18.7 \text{ LBS/AXLE}$

AXLE ATTACH BOLT & NUT

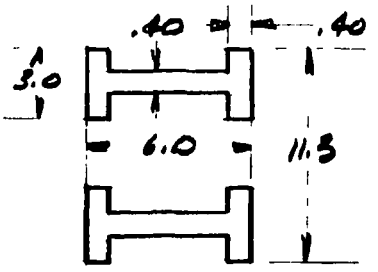
MAT'L 300M STEEL
ESTIMATE 5.0 LBS/AXLE

MAIN LANDING GEAR SHOCK STRUT SIDE BRACE





SECTION A-A



SECTION BB

LOWER BRACE

5.0 × .40 = 2.0 in²
5.0 × .50 × 2 = 5.0 in²
7.0 in²

UPPER BRACE

5.2 × .40 × 2 = 4.16
3.0 × .40 × 4 = 4.80
8.96 in²

- LOWER BRACE
  AREA = 7.0 IN² LENGTH = 36.0 MAT'L 300M STEEL
  ASSUME ½ VOLUME FOR FILLETS & END FITTING

  $(7.0\ in^2 \times 36.0\ in) \times 2 \times .283\ LBS/IN^3 = 142.5\ LBS.$

- UPPER BRACE
  AREA = 8.96 IN², LENGTH = 390 IN, MAT'L 300M
  ASSUME ½ VOLUME FOR FILLETS & END FITTINGS

  $(8.96\ IN^2 \times 39.0\ IN) \times 2 \times .283\ LBS/IN^3 = 198.0\ LBS$

SIDE BRACE CON'T

SIDE BRACE PINS

① OD = 4.0 D/t = 5.0 t = 4.0/5.0 = .80 ID = 2.40

$(4.0^2 - 2.4^2) \cdot 785 \times 5.0 \times .283\ \#/in^3 = 11.5$ LBS.

② OD = 3.0 D/t = 5.0 t = 3.0/5.0 = .60 ID = 1.80

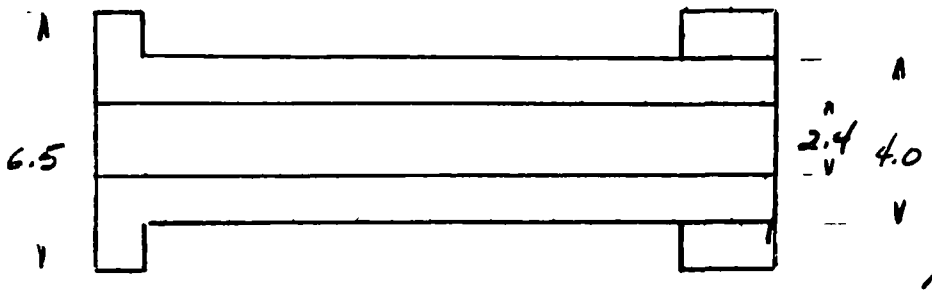
$(3.0^2 - 1.8^2) \cdot 785 \times 11.3 \times .283\ \#/in^3 = 14.5$ LBS

③ OD = 3.0 D/t = 5.0 t = 3.0/5.0 = .60 ID = 1.80

$(3.0^2 - 1.8^2) \cdot 785 \times 11.3 \times .283\ \#/in^3 = 14.5$ LBS

DESCRIPTION	LBS/STRUT
LOWER BRACE	142.5
UPPER BRACE	198.0
ATTACH PIN 1	11.5
" " 2	14.5
" " 3	14.5
	381.0

MAIN GEAR SHOCK STRUT TRUNNION PINS



MAT'L
300M STEEL
.283 #/in³

D/t = 5.0 OD = 4.0 t = 4.0/5.0 = .80" THEN ID = 2.4

$(4.0^2 - 2.4^2) \cdot .785 \times 15.0 = 120.0$ in³

$(6.5^2 - 4.0^2) \cdot .785 \times 30 = 61.5$ in³

181.5 in³

$181.5\ in^3 \times 2\ PINS/STRUT \times .283\ \#/in^3 = 102.5\ LBS/STRUT$

APPENDIX B

CURRENT INVENTORY OF
FLUIDS AND PROPELLANTS

CURRENT INVENTORY OF FLUIDS AND PROPELLANTS

PAGE 1 OF 2

CONFIGURATION | BY | DATE

SYSTEM	DENSITY (LB/FT^3)	CAPACITY (LB)	TOTAL (LB)	EXPENDABLES (NOMINAL (LB)	INFLIGHT LOSSES (LB)	RESERVES (LB)	RESIDUALS (LB)
PROPULSION – ASCENT		(3,111,074)	(3,063,715)	(3,038,600)	(20,320)	0	(4,796)
OXIDIZER (LO_2)	71.00	2,651,277	2,617,167	2,604,515	12,653	0	0
FUEL (LH_2)	4.395	459,797	440,860	434,085	6,775	0	0
PRESSURANT (GO_2/GH_2)		IN MAIN TANKS	5,688	0	892	0	4,796
PROPULSION – CRUISE			(135,045)	(121,000)	(0)	(10,000)	(4,045)
FUEL (JP-4)	48.17		135,045	121,000	0	10,000	4,045
PRESSURANT (AIR)			0	0	0	0	0
PROPULSION – AUXILIARY			(1,581)	(1212)	(9)	(54)	(306)
OXIDIZER (LO_2)							
MANEUVER			0	0	0	0	0
ATTITUDE CONTROL			1,277	991	4	48	234
FUEL (LH_2)							
MANEUVER			0	0	0	0	0
ATTITUDE CONTROL			283	221	5	6	51
PRESSURANT (GO_2/GH_2)							
MANEUVER			0	0	0	0	0
ATTITUDE CONTROL			21	0	0	0	21
ENVIRONMENTAL CONTROL			(30)	(0)	(0)	(0)	(30)
RADIATOR FLUID ( )			0	0	0	0	0
ATMOSPHERE (AIR)			28	0	0	0	28
OXYGEN			2	0	0	0	2
DILUENT ( )							
WATER			0	0	0	0	0
COOLING							
DRINKING							
WASH + PURIFICATION							
			(2,272)	(2035)	(0)	(191)	(46)
PRIME POWER							
RADIATOR FLUID ( )			0	0	0	0	0
FUEL CELL REACTANTS			0	0	0	0	0
OXIDIZER ( )							
FUEL ( )							
APU FUEL (LH_2)			186	168	0	14	4
APU FUEL (JP-4)			1,954	1,741	0	174	39
APU OXIDIZER (LO_2)			132	126	0	3	3

CURRENT INVENTORY OF FLUIDS AND PROPELLANTS (Continued)

PAGE 2 OF 2

CONFIGURATION | BY | DATE

SYSTEM	DENSITY (LB/FT^3)	CAPACITY (LB)	TOTAL (LB)	EXPENDABLES (NOMINAL (LB)	INFLIGHT LOSSES (LB)	RESERVES (LB)	RESIDUALS (LB)
HYDRAULIC SYSTEM			(5,381)	(0)	(0)	(0)	(5,381)
FLUID	53.0		5,381	0	0	0	5,381
OXIDIZER ( )							
FUEL ( )							
MISCELLANEOUS			(586)	(0)	(483)	(0)	(103)
APU & SERVICE PRESSURANT (GO_2)			2	0	0	0	2
APU & SERVICE PRESSURANT (GH_2)			14	0	0	0	14
SERVICE FUEL (LH_2)			142	0	139	0	3
SERVICE OXIDIZER (LO_2)			142	0	139	0	3
PNEUMATIC SYSTEM (HELIUM)			95	0	68	0	27
ELVIRONMENTAL CONTROL (FREON)			54	0	0	0	54
PROPELLANT FOR PURGE (JP-4)			137	0	137	0	0
START LOSSES-ASCENT PROP			(53,561)	(53,561)	(0)	(0)	(0)
FUEL (LH_2)			8,352	8,352	0	0	0
OXIDIZER (LO_2)			45,209	45,209	0	0	0

APPENDIX C

EASTERLY MISSION- DETAIL LISTING

BOOSTER MASS PROPERTIES

SEQUENCED MASS PROPERTIES SUMMARY 06/21/71
CANARD BOOSTER EASTERLY MISSION

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY X (INCH)	Y	Z	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-ROL
					(SLUG-FEET SQ./1000.)		
WING	57954.	3797.	0.	599.	2638.	244.	2809.
					0.	0.	16.
TAIL&CANARD	19214.	3278.	0.	475.	2466.	4689.	6714.
					0.	0.	889.
BODY	148599.	2816.	0.	395.	985.	20749.	20719.
					0.	0.	-109.
THERMAL PROT	84807.	3053.	0.	441.	3071.	14592.	16806.
					0.	0.	1124.
LANDING GEAR	25885.	3098.	0.	286.	153.	3035.	2960.
					0.	0.	-28.
ASCENT PROP	123320.	3708.	0.	430.	274.	4796.	4767.
					5.	0.	-235.
CRUISE PROP	37053.	2111.	0.	249.	235.	1196.	1302.
					1.	0.	203.
ORIENT SYS	5396.	2331.	14.	546.	8.	447.	453.
					-5.	0.	-1.
SURF CONTROL	11320.	3851.	0.	618.	883.	465.	1271.
					0.	0.	109.
PRIME POWER	3582.	3654.	0.	281.	1.	22.	22.
					0.	0.	0.
ELEC CON/DIS	1818.	2299.	0.	507.	2.	35.	34.
					0.	0.	4.
HYDRAULICS	7282.	3700.	0.	400.	4.	16.	16.
					0.	0.	0.
AVIONICS	4941.	1838.	0.	429.	5.	938.	937.
					0.	0.	9.
LAUNCH ESC	0.	0.	0.	0.	0.	0.	0.
					0.	0.	0.
ECLS	2058.	2352.	0.	435.	6.	482.	477.
					0.	0.	14.
PERS PROV	288.	1120.	0.	423.	0.	0.	0.
					0.	0.	0.
BALLAST	0.	0.	0.	0.	0.	0.	0.
					0.	0.	0.
PEND CHNGS	0.	0.	0.	0.	0.	0.	0.
					0.	0.	0.
GROWTH	42009.	3095.	0.	420.	91.	3264.	3264.
					0.	0.	0.
DRY WT	575526.	3164.	0.	426.	11725.	87174.	93850.
					-14.	2.	5388.
PERSONNEL	522.	1110.	0.	425.	0.	0.	0.
					0.	0.	0.
RESIDUALS	14707.	2837.	2.	421.	129.	2970.	3030.
					-4.	1.	49.

SEQUENCED MASS PROPERTIES SUMMARY 06/21/71
CANARD BOOSTER EASTERLY MISSION

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY (INCH) X	Y	Z	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-ROL
					(SLUG-FEET SQ./1000.)		
RESERVE	10245.	3801.	0.	599.	540.	172.	711.
					-1.	-0.	6.
LANDING WT	601000.	3165.	0.	429.	12459.	92094.	99304.
					-21.	3.	5690.
CRU RESR DMP	34000.	3845.	0.	600.	0.	0.	0.
					0.	0.	0.
END OF CRUSE	635000.	3201.	0.	438.	12663.	95512.	102519.
					-22.	3.	6499.
CRU PRO USED	87000.	2257.	0.	400.	715.	7096.	7588.
					0.	0.	882.
APU PROP	2035.	2023.	6.	540.	0.	-0.	0.
					0.	0.	0.
CRUISE START	724035.	3084.	0.	434.	13407.	117844.	125314.
					-22.	3.	7931.
INFLT LOSS	20812.	3313.	1.	402.	1.	2214.	2213.
					-4.	0.	-11.
ORIENT PROP	1212.	2023.	82.	400.	0.	0.	0.
					0.	0.	0.
PEND CHNGS	0.	0.	0.	0.	0.	0.	0.
					0.	0.	0.
BURN OUT WT	746059.	3089.	0.	433.	13415.	120589.	128055.
					-48.	3.	7898.
ASCENT PROP	759650.	2111.	0.	400.	0.	49800.	49800.
					0.	0.	0.
75% BURN	1505709.	2596.	0.	416.	13503.	248154.	255534.
					-23.	4.	10501.
ASCENT PROP	759650.	1938.	0.	400.	0.	36507.	36507.
					0.	0.	0.
50% BURN	2265359.	2375.	0.	411.	13531.	331865.	339216.
					-11.	4.	11666.
ASCENT PROP	759650.	1764.	0.	400.	0.	23195.	23195.
					0.	0.	0.

SEQUENCED MASS PROPERTIES SUMMARY 06/21/71
CANARD BOOSTER EASTERLY MISSION

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY (INCH) X	Y	Z	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-ROL
					(SLUG-FEET SQ./1000.)		
25% BURN	3025009.	2222.	0.	408.	13546.	400878.	408214.
					-3.	4.	12475.
ASCENT PROP	759650.	1605.	0.	400.	-0.	17496.	17496.
					0.	0.	0.
LAUNCH WT	3784659.	2098.	0.	406.	13554.	468285.	475613.
					3.	4.	13129.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES
CANARD BOOSTER EASTERLY MISSION UNITS - INCH										
WG CARY THRU	15414.	3696.	0.	570.	115.	60.	120.	0	0.	0.
TORO BOX LF	13410.	3848.	-490.	610.	206.	91.	204.	0	0.	0.
TORO BOX RT	13410.	3848.	490.	610.	206.	91.	204.	0	0.	0.
L.E. LF	4700.	3674.	-462.	606.	204.	119.	233.	0	0.	0.
L.E. RT	4700.	3674.	462.	606.	204.	119.	233.	0	0.	0.
T.E. LF	445.	3965.	-540.	614.	187.	52.	190.	0	0.	0.
T.E. RT	445.	3965.	540.	614.	187.	52.	190.	0	0.	0.
INBD ELE LF	1374.	3942.	-405.	590.	88.	60.	104.	0	0.	0.
INBD ELE RT	1374.	3942.	405.	590.	88.	60.	104.	0	0.	0.
OUTBD ELE LF	1341.	4087.	-680.	630.	88.	60.	104.	0	0.	0.
OUTBD ELE RT	1341.	4087.	680.	630.	88.	60.	104.	0	0.	0.

WING

W=	57954.0	X=	3796.66	Y=	.00	Z= 598.75
RAD OF GYRATION		KROL=	459.24	KPIT=	139.65	KYAW= 473.86
MOM OF INERTIA		ROLL=	2638077.	PITCH=	243951.	YAW= 2808812.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= 16168.

SUB-TOTAL - WING

W=	57954.0	X=	3796.66	Y=	.00	Z= 598.75
RAD OF GYRATION		KROL=	459.24	KPIT=	139.65	KYAW= 473.86
MOM OF INERTIA		ROLL=	2638077.	PITCH=	243951.	YAW= 2808812.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= 16168.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
TORO BOX LF	1126.	4075.	-920.	750.	78.	74.	34.	0	0.	0.
TORO BOX RT	1126.	4075.	920.	750.	78.	74.	34.	0	0.	0.
L.E. LF	481.	4020.	-920.	750.	78.	75.	35.	0	0.	0.
L.E. RT	481.	4020.	920.	750.	78.	75.	35.	0	0.	0.
T.E. LF	213.	4120.	-920.	750.	78.	72.	29.	0	0.	0.
T.E. RT	213.	4120.	920.	750.	78.	72.	29.	0	0.	0.
RUDDER LF	1032.	4155.	-920.	750.	78.	79.	43.	0	0.	0.
RUDDER RT	1032.	4155.	920.	750.	78.	79.	43.	0	0.	0.

DORSAL FIN

W= 5704.0	X=	4098.03	Y=	.00	Z=	750.00
RAD OF GYRATION	KROL=	923.30	KPIT=	90.76	KYAW=	922.10
MOM OF INERTIA	ROLL=	1049536.	PITCH=	10142.	YAW=	1046820.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	4.

TORO BOX LF	1655.	4160.	-920.	545.	78.	88.	58.	0	0.	0.
TORO BOX RT	1655.	4160.	920.	545.	78.	88.	58.	0	0.	0.
L.E. LF	577.	4105.	-920.	545.	78.	87.	57.	0	0.	0.
L.E. RT	577.	4105.	920.	545.	78.	87.	57.	0	0.	0.
T.E. LF	633.	4240.	-920.	545.	78.	91.	62.	0	0.	0.
T.E. RT	633.	4240.	920.	545.	78.	91.	62.	0	0.	0.

VENTRAL FIN

W= 5730.0	X=	4166.60	Y=	.00	Z=	545.00
RAD OF GYRATION	KROL=	923.30	KPIT=	99.08	KYAW=	922.95
MOM OF INERTIA	ROLL=	1054320.	PITCH=	12142.	YAW=	1053520.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	-1.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA (INCHES)		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
TORQ BOX LF	1972.	2022.	-290.	225.	81.	44.	89.	0	0.	0.
TORQ BOX RT	1972.	2022.	290.	225.	81.	44.	89.	0	0.	0.
L.E. LF	925.	1920.	-295.	223.	81.	20.	81.	0	0.	0.
L.E. RT	925.	1920.	295.	223.	81.	20.	81.	0	0.	0.
T.E. LF	190.	2111.	-295.	218.	81.	19.	80.	0	0.	0.
T.E. RT	190.	2111.	295.	218.	81.	19.	80.	0	0.	0.
JET FLAP LF	803.	2123.	-295.	211.	80.	13.	80.	0	0.	0.
JET FLAP RT	803.	2123.	295.	211.	80.	13.	80.	0	0.	0.

CANARD

W=	7780.0	X=	2022.94	Y=	.00	Z= 221.29
RAD OF GYRATION		KROL=	303.48	KPIT=	78.26	KYAW= 312.60
MOM OF INERTIA		ROLL=	154657.	PITCH=	10286.	YAW= 164091.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= -454.

SUB-TOTAL - TAIL&CANARD

W=	19214.0	X=	3278.25	Y=	.00	Z= 474.78
RAD OF GYRATION		KROL=	771.08	KPIT=	1063.36	KYAW= 1272.37
MOM OF INERTIA		ROLL=	2465770.	PITCH=	4689304.	YAW= 6713914.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= 888810.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES (INCHES)
SHELL	967.	1151.	0.	500.	68.	70.	70.	0	0.	0.
CREW DR	176.	1151.	0.	500.	68.	70.	70.	0	0.	0.
FLOOR	429.	1130.	0.	400.	37.	28.	50.	0	0.	0.
FWD BLKHD	85.	1070.	0.	415.	17.	8.	15.	0	0.	0.
AFT BLKHD	400.	1165.	0.	435.	46.	21.	40.	0	0.	0.
SIDE PANELS	78.	1130.	0.	416.	127.	29.	32.	0	0.	0.
COCKPIT ENCL	450.	1100.	0.	445.	32.	8.	32.	0	0.	0.
WND SHLD TPS	302.	1099.	0.	445.	32.	8.	32.	0	0.	0.

NOSE SECTION

W= 2887.0	X=	1133.48	Y=	.00	Z=	457.04
RAD OF GYRATION	KROL=	66.75	KPIT=	65.24	KYAW=	59.28
MOM OF INERTIA	ROLL=	2776.	PITCH=	2652.	YAW=	2190.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	262.

FWD BLKHD-02	300.	1220.	0.	400.	80.	21.	21.	0	0.	0.
SIDEWALL-02	9992.	1638.	0.	400.	150.	216.	216.	0	1235.	1883.
AFT BLKHD-02	4107.	1921.	0.	400.	161.	74.	74.	1	1883.	0.
BAFFLES-02	4650.	1638.	0.	400.	150.	216.	216.	0	1235.	1883.
CONTINGENCY	720.	1638.	0.	400.	150.	216.	216.	0	1235.	1883.

LOX TANK

W= 19769.0	X=	1690.45	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	151.55	KPIT=	232.26	KYAW=	232.26
MOM OF INERTIA	ROLL=	97996.	PITCH=	230171.	YAW=	230171.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	2.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
SIDEWALL	10626.	2023.	0.	400.	198.	161.	161.	0	1883.	2163.
FWD FRAME	2486.	1953.	0.	400.	160.	140.	140.	0	0.	0.
AFT FRAME	1423.	2093.	0.	400.	160.	140.	140.	0	0.	0.
JOINTS	1582.	2023.	0.	400.	198.	161.	161.	0	0.	0.
CONTINGENCY	600.	2023.	0.	400.	198.	161.	161.	0	0.	0.

INTERTANK

W= 16717.0	X=	2018.55	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	189.80	KPIT=	159.93	KYAW=	159.93
MOM OF INERTIA	ROLL=	129978.	PITCH=	92284.	YAW=	92284.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	2.

CANARD PKUP	578.	2023.	0.	230.	140.	17.	140.	0	1883.	2163.

CANARD PKUP

W= 578.0	X=	2023.00	Y=	.00	Z=	230.00
RAD OF GYRATION	KROL=	140.00	KPIT=	17.00	KYAW=	140.00
MOM OF INERTIA	ROLL=	2445.	PITCH=	36.	YAW=	2445.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

FWD BLKHD-H2	2631.	2125.	0.	400.	161.	74.	74.	1	2163.	0.
SIDEWALL-H2	51053.	2871.	0.	400.	198.	424.	424.	0	2163.	3553.
AFT BLKHD-H2	3223.	3591.	0.	400.	161.	74.	74.	1	3553.	0.
BAFFLES-H2	1910.	2858.	0.	400.	198.	424.	424.	0	2163.	3553.
CONTINGENCY	2845.	2871.	0.	400.	198.	424.	424.	0	2163.	3553.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA (INCHES)		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES

LH2 TANK

W= 61662.0 X= 2876.40 Y= .00 Z= 400.00
RAD OF GYRATION KROL= 194.79 KPIT= 462.65 KYAW= 462.65
MOM OF INERTIA ROLL= 504986. PITCH= 2848813. YAW= 2848815.
PROD OF INERTIA ROL-PIT= 0. PIT-YAW= 0. YAW-ROL= 0.

INSUL-H2 TNK	4113.	2858.	0.	400.	198.	430.	430.	0	2163.	3553.
NOSE GEAR DR	355.	2088.	0.	200.	32.	40.	51.	0	1957.	2093.
MAIN GR DRS	947.	3660.	0.	200.	50.	20.	50.	0	3630.	3700.
NOSE GR PKUP	875.	2088.	0.	220.	110.	6.	110.	1	2088.	0.
MAIN GR PKUP	2354.	3660.	0.	220.	110.	10.	110.	1	3663.	0.
WING PICKUP	545.	3325.	0.	565.	115.	70.	139.	0	3553.	3792.
THRUST STRUC	37797.	3737.	0.	400.	140.	147.	147.	0	3553.	3930.

BODY

W= 46986.0 X= 3606.70 Y= .00 Z= 384.00
RAD OF GYRATION KROL= 153.74 KPIT= 401.59 KYAW= 398.66
MOM OF INERTIA ROLL= 239711. PITCH= 1635596. YAW= 1611744.
PROD OF INERTIA ROL-PIT= 0. PIT-YAW= 0. YAW-ROL= 62391.

SUB-TOTAL - BODY

W= 148599.0 X= 2815.85 Y= .00 Z= 395.39
RAD OF GYRATION KROL= 175.28 KPIT= 804.31 KYAW= 803.74
MOM OF INERTIA ROLL= 985437. PITCH= 20748720. YAW= 20719296.
PROD OF INERTIA ROL-PIT= 0. PIT-YAW= 0. YAW-ROL= -108622.

TPS WING LF	8225.	3855.	-522.	603.	187.	219.	284.	0	0.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES (INCHES)
TPS WING RT	8225.	3855.	522.	603.	187.	219.	284.	0	0.	0.
TPS FIN LF	3298.	4055.	-915.	608.	148.	176.	107.	0	0.	0.
TPS FIN RT	3298.	4055.	915.	608.	148.	176.	107.	0	0.	0.
TPS CNRD LF	2262.	2012.	-305.	228.	86.	75.	111.	0	0.	0.
TPS CNRD RT	2262.	2012.	305.	228.	86.	75.	111.	0	0.	0.
TPS BODY	47969.	2662.	0.	386.	194.	792.	796.	0	0.	0.
TPS BASE	5678.	3885.	0.	425.	164.	105.	133.	0	0.	0.
STAND OFFS	3327.	2754.	0.	432.	185.	707.	707.	0	0.	0.
INSTRUMNTATN	263.	2750.	0.	435.	180.	650.	700.	0	0.	0.

THERMAL PROT

W=	84807.0	X=	3052.84	Y=	.00	Z= 441.50
RAD OF GYRATION		KROL=	409.58	KPIT=	892.83	KYAW= 958.17
MOM OF INERTIA		ROLL=	3070744.	PITCH=	14591655.	YAW= 16805600.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= 1124424.

SUB-TOTAL - THERMAL PROT

W=	84807.0	X=	3052.84	Y=	.00	Z= 441.50
RAD OF GYRATION		KROL=	409.58	KPIT=	892.83	KYAW= 958.17
MOM OF INERTIA		ROLL=	3070744.	PITCH=	14591656.	YAW= 16805600.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= 1124425.

LND GEAR FWD	7530.	2080.	0.	220.	9.	35.	36.	1	2082.	0.
MAIN LND GR	15060.	3675.	0.	250.	115.	17.	47.	1	3666.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	

FWD+AFT GEAR

W= 22590.0	X= 3143.33	Y= .00	Z= 240.00		
RAD OF GYRATION	KROL= 95.10	KPIT= 752.42	KYAW= 753.16		
MOM OF INERTIA	ROLL= 44095.	PITCH= 2760400.	YAW= 2765783.		
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 51847.		

AFT ATTACH	2320.	3036.	0.	600.	200.	50.	50.	0	0.	0.
FWD ATTACH	508.	2100.	0.	600.	200.	20.	20.	0	0.	0.
SEP MECH	310.	2100.	0.	600.	200.	20.	20.	0	0.	0.
CONTINGENCY	157.	2700.	0.	600.	200.	20.	20.	0	0.	0.

BOO/ORB CONN

W= 3295.0	X= 2787.62	Y= .00	Z= 600.00		
RAD OF GYRATION	KROL= 200.00	KPIT= 403.81	KYAW= 403.81		
MOM OF INERTIA	ROLL= 28448.	PITCH= 115970.	YAW= 115970.		
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= -1.		

SUB-TOTAL - LANDING GEAR

W= 25885.0	X= 3098.05	Y= .00	Z= 285.83		
RAD OF GYRATION	KROL= 165.47	KPIT= 737.08	KYAW= 727.91		
MOM OF INERTIA	ROLL= 152981.	PITCH= 3035343.	YAW= 2960287.		
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= -27631.		

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
MANIFOLD	1101.	3613.	0.	400.	110.	40.	40.	1	3616.	0.
GIMBAL BELL	1548.	3700.	0.	400.	10.	90.	90.	1	3700.	0.
DUCTS	1510.	3730.	0.	400.	35.	35.	35.	1	3670.	0.
POGO ACCUMS	754.	3763.	0.	420.	110.	90.	110.	0	0.	0.
MANIFLD BELL	136.	3613.	0.	400.	110.	40.	40.	1	3658.	0.
ISOLATE VALS	1740.	3640.	0.	400.	90.	80.	80.	1	3678.	0.
VALVE FLANGE	288.	3640.	0.	400.	110.	40.	40.	1	3678.	0.
ENG FLANGES	180.	3796.	0.	400.	110.	40.	40.	1	3740.	0.
MAIN DUCTS	2496.	2260.	0.	592.	11.	450.	450.	0	1997.	3610.
MN DUCT BELW	1200.	2070.	0.	570.	11.	190.	100.	1	2083.	0.
SUPPORTS	2738.	3222.	0.	400.	90.	80.	80.	1	3206.	0.

LOX FEED

W= 13691.0	X=	3190.30	Y=	.00	Z=	451.01
RAD OF GYRATION	KROL=	108.06	KPIT=	670.09	KYAW=	663.53
MOM OF INERTIA	ROLL=	34503.	PITCH=	1326877.	YAW=	1301045.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	-143691.

GIMBAL BELL	1062.	3710.	0.	400.	10.	90.	90.	1	3694.	0.
DUCTS	860.	3700.	0.	400.	35.	35.	35.	1	3696.	0.
DUCT INSUL	695.	3700.	0.	400.	35.	35.	35.	1	3696.	0.
ISOLATE VALS	1740.	3680.	0.	400.	55.	25.	25.	1	3680.	0.
VALVE FLANGE	288.	3680.	0.	400.	55.	25.	25.	1	3680.	0.
ENG FLANGES	180.	3796.	0.	400.	100.	35.	35.	1	3740.	0.
SUPPORTS	1206.	3698.	0.	400.	60.	35.	35.	1	3692.	0.

ITEM	WEIGHT	CENTER OF GRAVITY			RADII OF GYRATION			DIST. DATA		
	(LB)	X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
		(INCHES)			(INCHES)				(INCHES)	

LH2 FEED

W= 6031.0	X=	3697.50	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	48.67	KPIT=	51.76	KYAW=	51.76
MOM OF INERTIA	ROLL=	3084.	PITCH=	3488.	YAW=	3488.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	2.

FILL-DRN VAL	100.	3805.	-112.	585.	5.	5.	5.	1	3805.	0.
ISOLATE VAL	100.	3730.	-112.	528.	5.	5.	5.	1	3730.	0.
DUMP VALVE	100.	3805.	-112.	585.	5.	5.	5.	1	3805.	0.
GIMBAL BELOW	56.	3730.	-112.	528.	30.	58.	50.	0	3600.	3864.
DISCONNECT	15.	3825.	-112.	590.	2.	2.	5.	1	3825.	0.
DUCT FLANGES	62.	3780.	-112.	575.	30.	58.	50.	0	3720.	3864.
DUCTING	77.	3758.	-112.	550.	30.	58.	50.	0	3600.	3864.
RE-ENTRY-V-D	42.	3740.	-225.	560.	85.	43.	100.	1	3740.	0.
SUPTS MISC	138.	3772.	-120.	563.	30.	58.	50.	1	3720.	3864.

LO2 FILL FRN

W= 690.0	X=	3770.43	Y=	-120.48	Z=	561.50
RAD OF GYRATION	KROL=	45.46	KPIT=	55.25	KYAW=	58.20
MOM OF INERTIA	ROLL=	308.	PITCH=	455.	YAW=	505.
PROD OF INERTIA	ROL-PIT=	31.	PIT-YAW=	1.	YAW-ROL=	90.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES
FILL-DRN VAL	100.	3805.	112.	585.	5.	5.	5.	1	3805.	0.
ISOLATE VAL	100.	3730.	112.	528.	5.	5.	5.	1	3730.	0.
DUMP VALVE	100.	3805.	112.	585.	5.	5.	5.	1	3805.	0.
GIMBAL BELOW	56.	3730.	112.	528.	30.	58.	50.	0	3600.	3864.
DISCONNECT	15.	3825.	112.	590.	2.	2.	5.	1	3825.	0.
DUCT FLANGES	62.	3780.	112.	575.	30.	58.	50.	0	3600.	3864.
DUCTING	166.	3758.	112.	550.	30.	58.	50.	0	3600.	3864.
RE-ENTRY-V-D	42.	3740.	225.	560.	85.	43.	100.	1	3740.	0.
SUPTS MISC	160.	3770.	119.	561.	30.	58.	50.	0	3720.	3864.

LH2 FILL DRN

W= 801.0	X=	3768.69	Y=	119.32	Z=	559.86
RAD OF GYRATION	KROL=	43.86	KPIT=	55.93	KYAW=	57.38
MOM OF INERTIA	ROLL=	333.	PITCH=	541.	YAW=	569.
PROD OF INERTIA	ROL-PIT=	-29.	PIT-YAW=	0.	YAW-ROL=	92.

PRESS LINE	577.	2478.	-40.	595.	2.	660.	660.	0	1235.	3600.
PRESS MANFLD	61.	3750.	0.	470.	150.	120.	120.	0	3720.	3792.
GRND PRESS A	4.	3812.	0.	600.	10.	10.	10.	1	3812.	0.
GRND CK OUT	3.	1220.	0.	480.	4.	4.	4.	1	1220.	0.
ISOLATE VAL	200.	1180.	0.	412.	5.	5.	5.	1	1180.	0.
VNT-RELF VAL	200.	1173.	0.	360.	5.	5.	5.	1	1173.	0.
CHECK VALS	40.	1195.	0.	451.	2.	2.	2.	1	1195.	0.
VNT DUCT ASY	181.	1180.	0.	400.	32.	32.	5.	1	1180.	0.
DUCT FLANGES	83.	1177.	0.	386.	32.	32.	5.	1	1177.	0.
DIFFUSR ASSY	37.	1218.	0.	382.	22.	10.	22.	1	1235.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES
SUPTS MISC	346.	1856.	-17.	484.	32.	32.	10.	0	1235.	2788.

LO2 PRES-VNT

W= 1732.0	X=	1844.33	Y=	-16.72	Z=	481.70
RAD OF GYRATION	KROL=	97.15	KPIT=	783.48	KYAW=	778.37
MOM OF INERTIA	ROLL=	3528.	PITCH=	229474.	YAW=	226493.
PROD OF INERTIA	ROL-PIT=	-3172.	PIT-YAW=	-567.	YAW-ROL=	18312.

PRESS LINE	397.	2932.	40.	595.	2.	420.	420.	0	2163.	3600.
PPESS MANFLD	61.	3750.	0.	470.	150.	120.	120.	0	3720.	3792.
GRND PRESS A	4.	3812.	0.	600.	10.	10.	10.	1	3812.	0.
GRND CK OUT	3.	2143.	0.	600.	4.	4.	4.	1	2143.	0.
ISOLATE VAL	200.	2033.	0.	475.	5.	5.	5.	1	2033.	0.
VNT-RELF VAL	200.	2019.	0.	435.	5.	5.	5.	1	2019.	0.
CHECK VALS	40.	2103.	0.	560.	2.	2.	2.	1	2103.	0.
VNT DUCT ASY	222.	2053.	0.	520.	32.	32.	5.	1	2053.	0.
DUCT FLANGES	83.	2026.	0.	455.	32.	32.	5.	1	2026.	0.
DIFFUSR ASSY	37.	2073.	0.	438.	22.	10.	22.	1	2163.	0.
SUPTS MISC	312.	2423.	12.	518.	32.	32.	10.	0	2163.	2788.

LH2 PRES-VNT

W= 1559.0	X=	2415.36	Y=	12.59	Z=	516.04
RAD OF GYRATION	KROL=	68.84	KPIT=	512.67	KYAW=	509.49
MOM OF INERTIA	ROLL=	1595.	PITCH=	88443.	YAW=	87349.
PROD OF INERTIA	ROL-PIT=	1777.	PIT-YAW=	272.	YAW-ROL=	5290.

ASCENT ENGS	89940.	3840.	0.	425.	100.	58.	58.	1	3634.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES
TVC	5516.	3824.	0.	425.	100.	50.	100.	1	3824.	0.
CHILLDOWN	632.	3700.	0.	425.	100.	10.	10.	1	3805.	0.
PNEU SYS	2129.	3667.	0.	400.	100.	50.	50.	1	3667.	0.
HYDR CONTRL	24.	3700.	0.	400.	100.	100.	100.	0	0.	0.
PROP LVL SEN	75.	1884.	0.	400.	2.	140.	140.	1	1884.	0.
MISC-CONTIN	500.	3721.	0.	400.	100.	40.	40.	1	3723.	0.

ASCENT PROP

W= 98816.0	X=	3832.35	Y=	.00	Z=	424.31
RAD OF GYRATION	KROL=	100.05	KPIT=	83.93	KYAW=	86.29
MOM OF INERTIA	ROLL=	213483.	PITCH=	150238.	YAW=	158807.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	3070.

SUB-TOTAL - ASCENT PROP

W= 123320.0	X=	3707.88	Y=	.03	Z=	429.70
RAD OF GYRATION	KROL=	101.42	KPIT=	424.46	KYAW=	423.19
MOM OF INERTIA	ROLL=	273761.	PITCH=	4795550.	YAW=	4766925.
PROD OF INERTIA	ROL-PIT=	4914.	PIT-YAW=	67.	YAW-ROL=	-234501.

ENGINES	26140.	2016.	0.	230.	120.	60.	125.	1	2016.	0.
ACCESSORIES	1814.	2016.	0.	200.	120.	60.	125.	1	2016.	0.
AIR INDUCTN	1108.	2016.	0.	200.	120.	60.	125.	0	0.	0.
ENG MOUNT	195.	2016.	0.	200.	120.	60.	125.	0	0.	0.
FIREWALLS	990.	2016.	0.	200.	120.	60.	125.	0	0.	0.
EXHAUST SYS	1600.	2016.	0.	200.	120.	60.	125.	0	0.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
TANK FWD	1492.	2023.	0.	370.	150.	53.	53.	1	2023.	0.
LFT WG TANK	582.	3845.	-500.	600.	190.	155.	230.	1	3845.	0.
RT WG TANK	582.	3845.	500.	600.	190.	155.	230.	1	3845.	0.
FEED-TRANSFR	886.	2768.	0.	400.	100.	500.	500.	0	2023.	3660.
PRESS-VENT	246.	2770.	0.	400.	150.	700.	700.	0	2023.	3660.
FIL-DRN-DUMP	139.	3603.	0.	400.	200.	70.	70.	1	3603.	0.
PNEU-AC-CONT	111.	3000.	0.	400.	200.	460.	460.	0	2023.	3660.
BLEED-AIR SP	46.	2023.	0.	400.	80.	5.	80.	1	2023.	0.
PROP LVL SEN	130.	2895.	40.	400.	200.	10.	200.	1	2895.	0.
CONTINGENCY	992.	2111.	0.	216.	100.	200.	200.	1	2114.	0.

CRUISE PROP

W=	37053.0	X=	2111.26	Y=	.14	Z= 249.41
RAD OF GYRATION		KROL=	171.53	KPIT=	386.78	KYAW= 403.46
MOM OF INERTIA		ROLL=	235307.	PITCH=	1196432.	YAW= 1301820.
PROD OF INERTIA		ROL-PIT=	880.	PIT-YAW=	169.	YAW-ROL= 202818.

SUB-TOTAL - CRUISE PROP

W=	37053.0	X=	2111.26	Y=	.14	Z= 249.41
RAD OF GYRATION		KROL=	171.53	KPIT=	386.78	KYAW= 403.46
MOM OF INERTIA		ROLL=	235307.	PITCH=	1196432.	YAW= 1301820.
PROD OF INERTIA		ROL-PIT=	880.	PIT-YAW=	169.	YAW-ROL= 202818.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
THRUSTERS	549.	2371.	0.	515.	110.	752.	758.	0	0.	0.
TANKS + SUPT	510.	2040.	15.	555.	20.	20.	20.	0	0.	0.
ACCUM + SUPT	1292.	1976.	50.	565.	64.	40.	64.	0	0.	0.
CONDITIONING	809.	2033.	0.	520.	64.	40.	64.	0	0.	0.
FILL SYS	110.	2030.	0.	580.	20.	20.	20.	0	0.	0.
FEED SYS	1524.	2940.	0.	550.	110.	752.	758.	0	0.	0.
PRESS SYS	148.	2030.	0.	560.	20.	20.	20.	0	0.	0.
VENT SYS	216.	2030.	0.	575.	20.	20.	20.	0	0.	0.
INSTRUMENT	238.	2510.	20.	505.	20.	20.	20.	0	0.	0.

ORIENT SYS

W=	5396.0	X=	2331.34	Y=	14.27	Z= 545.91
RAD OF GYRATION		KROL=	84.87	KPIT=	619.82	KYAW= 623.40
MOM OF INERTIA		ROLL=	8388.	PITCH=	447437.	YAW= 452622.
PROD OF INERTIA		ROL-PIT=	-5252.	PIT-YAW=	239.	YAW-ROL= -1324.

SUB-TOTAL - ORIENT SYS

W=	5396.0	X=	2331.34	Y=	14.27	Z= 545.91
RAD OF GYRATION		KROL=	84.87	KPIT=	619.82	KYAW= 623.40
MOM OF INERTIA		ROLL=	8388.	PITCH=	447437.	YAW= 452622.
PROD OF INERTIA		ROL-PIT=	-5252.	PIT-YAW=	239.	YAW-ROL= -1324.

S/C ELEVONS	8617.	3900.	0.	600.	500.	50.	500.	0	0.	0.
S/C RUDDERS	2124.	4130.	0.	800.	900.	50.	900.	0	0.	0.
S/C CANARD	579.	2100.	0.	220.	300.	0.	300.	0	0.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA (INCHES)		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES

SURF CONTROL

W= 11320.0	X=	3851.09	Y=	.00	Z=	618.09
RAD OF GYRATION	KROL=	601.21	KPIT=	436.12	KYAW=	721.22
MOM OF INERTIA	ROLL=	883145.	PITCH=	464720.	YAW=	1270902.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	108736.

SUB-TOTAL - SURF CONTROL

W= 11320.0	X=	3851.09	Y=	.00	Z=	618.09
RAD OF GYRATION	KROL=	601.21	KPIT=	436.12	KYAW=	721.22
MOM OF INERTIA	ROLL=	883145.	PITCH=	464720.	YAW=	1270902.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	108736.

TURBO PWR SY	302.	3720.	0.	285.	22.	21.	28.	0	0.	0.
AIR PWR UNIT	1816.	3720.	0.	285.	22.	21.	28.	0	0.	0.
HEAT EXCHANG	173.	3710.	0.	270.	20.	10.	10.	0	0.	0.
ALTERNATORS	184.	3720.	0.	280.	22.	21.	28.	0	0.	0.
DISTRIB SYS	295.	3690.	0.	274.	50.	80.	80.	0	0.	0.
GEAR BOX	451.	3220.	0.	280.	10.	20.	20.	0	0.	0.
BATTERY	35.	3705.	0.	275.	5.	5.	5.	0	0.	0.
SUPPORTS	326.	3720.	0.	275.	40.	20.	20.	0	0.	0.

PRIME POWER

W= 3582.0	X=	3653.95	Y=	.00	Z=	281.48
RAD OF GYRATION	KROL=	26.79	KPIT=	167.68	KYAW=	168.27
MOM OF INERTIA	ROLL=	555.	PITCH=	21739.	YAW=	21892.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	91.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA (INCHES)		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES

SUB-TOTAL - PRIME POWER

W= 3582.0	X= 3653.95	Y= .00	Z= 281.48
RAD OF GYRATION	KROL= 26.79	KPIT= 167.68	KYAW= 168.27
MOM OF INERTIA	ROLL= 555.	PITCH= 21739.	YAW= 21892.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 91.

PWR CONVER	192.	2352.	0.	452.	30.	30.	20.	0	0.	0.
PWR CONTROL	484.	2116.	0.	481.	50.	50.	50.	0	0.	0.
PWR DIST	853.	2501.	0.	550.	50.	200.	200.	0	0.	0.
LIGHTS	126.	1550.	0.	390.	50.	50.	50.	0	0.	0.
SUPTS + INST	163.	2300.	0.	510.	70.	80.	80.	0	0.	0.

ELEC CON/DIS

W= 1818.0	X= 2298.83	Y= .00	Z= 506.60
RAD OF GYRATION	KROL= 69.73	KPIT= 299.72	KYAW= 295.74
MOM OF INERTIA	ROLL= 1908.	PITCH= 35250.	YAW= 34320.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 4359.

SUB-TOTAL - ELEC CON/DIS

W= 1818.0	X= 2298.83	Y= .00	Z= 506.60
RAD OF GYRATION	KROL= 69.73	KPIT= 299.72	KYAW= 295.74
MOM OF INERTIA	ROLL= 1908.	PITCH= 35250.	YAW= 34320.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 4359.

ITEM	WEIGHT	CENTER OF GRAVITY			RADII OF GYRATION			DIST. DATA		
	(LB)	X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
		(INCHES)			(INCHES)				(INCHES)	
PWR SUPPLY	900.	3700.	0.	400.	50.	100.	100.	0	0.	0.
DIST CONTRL	5879.	3700.	0.	400.	50.	100.	100.	0	0.	0.
AUX SYSTEMS	132.	3700.	0.	400.	50.	100.	100.	0	0.	0.
SUPPORTS	371.	3700.	0.	400.	50.	100.	100.	0	0.	0.

HYDRAULICS

W= 7282.0	X=	3700.00	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	50.00	KPIT=	100.04	KYAW=	100.04
MOM OF INERTIA	ROLL=	3929.	PITCH=	15732.	YAW=	15732.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	1.

SUB-TOTAL - HYDRAULICS

W= 7282.0	X=	3700.00	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	50.00	KPIT=	100.04	KYAW=	100.04
MOM OF INERTIA	ROLL=	3929.	PITCH=	15732.	YAW=	15732.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	1.

IMU	140.	1140.	0.	370.	10.	10.	10.	0	0.	0.
NAVIG BASE	80.	1140.	0.	370.	5.	6.	6.	0	0.	0.
MOUNT STRUC	10.	1140.	0.	370.	4.	4.	4.	0	0.	0.
EO BAY STRUC	24.	1140.	0.	370.	10.	10.	12.	0	0.	0.
CIRCUITRY	24.	1140.	0.	370.	5.	5.	5.	0	0.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	

GUID&NAVIG

W= 278.0	X= 1140.00	Y= .00	Z= 370.00
RAD OF GYRATION	KROL= 8.30	KPIT= 8.38	KYAW= 8.60
MOM OF INERTIA	ROLL= 4.	PITCH= 4.	YAW= 4.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 0.

THRUST ELEC	70.	2023.	0.	500.	5.	6.	6.	0	0.	0.
ACTUATON EL	184.	3700.	0.	400.	11.	11.	11.	0	0.	0.
TVC ACTU EL	342.	3720.	0.	400.	15.	15.	15.	0	0.	0.
RATE GYRO	16.	2720.	0.	600.	3.	3.	3.	0	0.	0.
TEM&PRES SEN	10.	2720.	0.	400.	0.	0.	0.	0	0.	0.
ACCELEROMTR	6.	2023.	0.	500.	1.	1.	1.	0	0.	0.
ST PRES SEN	10.	2720.	0.	400.	0.	0.	0.	0	0.	0.
PITOT ASY	215.	1055.	0.	370.	2.	21.	21.	0	0.	0.
PITCH SENS	4.	1055.	0.	370.	0.	0.	0.	0	0.	0.
SIDE SLIP SN	4.	1055.	0.	370.	0.	0.	0.	0	0.	0.
NORM PRES SN	4.	1055.	0.	370.	0.	0.	0.	0	0.	0.
MOUNT STRUC	28.	2023.	0.	500.	50.	400.	400.	0	0.	0.
EQ BAY STRUC	91.	2023.	0.	500.	50.	400.	400.	0	0.	0.
CIRCUITRY	175.	2720.	0.	500.	50.	400.	400.	0	0.	0.

FLGT CONTROL

W= 1159.0	X= 2727.29	Y= .00	Z= 428.81
RAD OF GYRATION	KROL= 61.75	KPIT= 1056.42	KYAW= 1054.96
MOM OF INERTIA	ROLL= 954.	PITCH= 279183.	YAW= 278410.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= -539.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES
CENTRAL COMP	340.	1100.	0.	370.	15.	15.	15.	0	0.	0.
SYS CONTROL	7.	1100.	0.	370.	1.	1.	1.	0	0.	0.
MEMORY MECH	20.	1100.	0.	370.	3.	3.	3.	0	0.	0.
MEMORY ELECT	12.	1100.	0.	370.	2.	2.	2.	0	0.	0.
AREA DIU	162.	2023.	0.	500.	11.	11.	11.	0	0.	0.
CREW STA DIU	114.	1070.	0.	420.	8.	8.	8.	0	0.	0.
IMU DIU	20.	1100.	0.	370.	3.	3.	3.	0	0.	0.
DATA BUS	36.	1070.	0.	420.	4.	4.	4.	0	0.	0.
INPUT/OUTPUT	24.	1070.	0.	420.	3.	3.	3.	0	0.	0.
MAINT RECORD	100.	1070.	0.	410.	8.	8.	8.	0	0.	0.
MOUNT STRUCT	33.	1100.	0.	370.	10.	10.	12.	0	0.	0.
EO BAY STRUC	107.	1100.	0.	370.	10.	10.	12.	0	0.	0.
CIRCUITRY	242.	1100.	0.	400.	20.	20.	20.	0	0.	0.
DATA MANGMNT										
W= 1217.0	X=	1216.11	Y=	.00	Z=	403.71				
RAD OF GYRATION	KROL=	44.31	KPIT=	319.51	KYAW=	316.72				
MOM OF INERTIA	ROLL=	516.	PITCH=	26816.	YAW=	26350.				
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	3085.				
AUDIO CONTRL	36.	1070.	0.	430.	4.	4.	4.	0	0.	0.
UHF XCEIVER	36.	2023.	0.	500.	4.	4.	4.	0	0.	0.
UHF ANTENNA	39.	2023.	0.	400.	200.	200.	200.	0	0.	0.
UHF INSTL	46.	2023.	0.	500.	4.	4.	5.	0	0.	0.
DME RECVR	90.	2023.	0.	520.	7.	7.	7.	0	0.	0.
DME ANTENNA	4.	2023.	0.	400.	200.	200.	200.	0	0.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES (INCHES)
DME INSTL	50.	2023.	0.	520.	7.	7.	7.	0	0.	0.
GLD SLOP REC	12.	3710.	0.	400.	2.	2.	2.	0	0.	0.
GLD SLOP ANT	6.	4245.	0.	420.	990.	2.	990.	0	0.	0.
GLD SLOP INS	33.	3710.	0.	400.	4.	4.	4.	0	0.	0.
VOR/LOC REC	60.	2023.	0.	500.	4.	5.	5.	0	0.	0.
VOR/LOC ANT	32.	1026.	0.	400.	4.	3.	3.	0	0.	0.
VOR/LOC INST	66.	2023.	0.	500.	5.	6.	6.	0	0.	0.
RADAR ALT	63.	3700.	0.	400.	5.	6.	6.	0	0.	0.
RADAR ANT	6.	3700.	0.	220.	2.	2.	2.	0	0.	0.
RADAR INSTL	71.	3700.	0.	400.	5.	6.	6.	0	0.	0.
ATC XPONDER	20.	2023.	0.	510.	3.	3.	3.	0	0.	0.
ATC ANT	1.	2023.	0.	200.	0.	0.	0.	0	0.	0.
ATC INSTL	13.	2023.	0.	510.	4.	4.	4.	0	0.	0.
MOUNT STRUCT	17.	2023.	0.	500.	4.	4.	4.	0	0.	0.
EO BAY STRUC	57.	2023.	0.	500.	4.	4.	4.	0	0.	0.
CIRCUITRY	95.	2023.	0.	500.	5.	5.	5.	0	0.	0.

COMMUNICATN

W=	853.0	X=	2325.24	Y=	.00	Z= 468.05
RAD OF GYRATION	KROL=	108.95	KPIT=	797.30	KYAW=	799.77
MOM OF INERTIA	ROLL=	2185.	PITCH=	117036.	YAW=	117765.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	-4343.

DIS&CON UNIT	613.	1070.	0.	430.	10.	7.	10.	0	0.	0.
MOUNT STRUCT	27.	1070.	0.	430.	10.	7.	10.	0	0.	0.
WINDOW MOUNT	6.	1080.	0.	435.	1.	1.	1.	0	0.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
CIRCUITRY	162.	1070.	0.	430.	10.	7.	10.	0	0.	0.
CONTINGENCY	626.	2040.	0.	450.	40.	500.	500.	0	1092.	1992.

DISPLAY&CONT

W=	808.0	X=	1070.07	Y=	.00	Z= 430.04
RAD OF GYRATION	KROL=	9.97	KPIT=	7.08	KYAW=	10.03
MOM OF INERTIA	ROLL=	17.	PITCH=	9.	YAW=	18.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

AVIONICS

W=	626.0	X=	2040.00	Y=	.00	Z= 450.00
RAD OF GYRATION	KROL=	40.00	KPIT=	500.00	KYAW=	500.00
MOM OF INERTIA	ROLL=	216.	PITCH=	33779.	YAW=	33779.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

SUB-TOTAL - AVIONICS

W=	4941.0	X=	1838.28	Y=	.00	Z= 428.98
RAD OF GYRATION	KROL=	65.75	KPIT=	937.97	KYAW=	937.36
MOM OF INERTIA	ROLL=	4610.	PITCH=	938268.	YAW=	937049.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	8702.

ITEM	WEIGHT	CENTER OF GRAVITY			RADII OF GYRATION			DIST. DATA		
	(LB)	X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
		(INCHES)			(INCHES)				(INCHES)	

SUB-TOTAL - LAUNCH ESC

W=	.0	X=	.00	Y=	.00	Z=	.00
RAD OF GYRATION	KROL=		.00	KPIT=	.00	KYAW=	.00
MOM OF INERTIA	ROLL=		0.	PITCH=	0.	YAW=	0.
PROD OF INERTIA	ROL-PIT=		0.	PIT-YAW=	0.	YAW-ROL=	0.

AIR TANKS	38.	1190.	0.	360.	10.	10.	10.	0	0.	0.
PRES REL VAL	5.	1190.	0.	360.	1.	1.	1.	0	0.	0.
PRESS REG	4.	1190.	0.	360.	1.	1.	1.	0	0.	0.
SHUT-OFF VAL	3.	1190.	0.	360.	1.	1.	1.	0	0.	0.
CK VAL	2.	1190.	0.	360.	1.	1.	1.	0	0.	0.
DISCONNECT	1.	1190.	0.	360.	1.	1.	1.	0	0.	0.
TEMP XDUCER	2.	1190.	0.	360.	0.	0.	0.	0	0.	0.
PRESS XDUCER	12.	1190.	0.	360.	0.	0.	0.	0	0.	0.

ATMOS SUPPLY

W=	67.0	X=	1190.00	Y=	.00	Z=	360.00
RAD OF GYRATION	KROL=		7.55	KPIT=	7.51	KYAW=	7.51
MOM OF INERTIA	ROLL=		1.	PITCH=	1.	YAW=	1.
PROD OF INERTIA	ROL-PIT=		0.	PIT-YAW=	0.	YAW-ROL=	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
O2 TANK	8.	1170.	0.	360.	3.	3.	3.	0	0.	0.
PRES REL VAL	3.	1170.	0.	360.	1.	1.	1.	0	0.	0.
PRESS REG	2.	1170.	0.	360.	1.	1.	1.	0	0.	0.
SHUT-OFF VAL	2.	1170.	0.	360.	1.	1.	1.	0	0.	0.
CK VAL	2.	1170.	0.	360.	1.	1.	1.	0	0.	0.
DISCONNECT	1.	1170.	0.	360.	1.	1.	1.	0	0.	0.
MASK CONNEC	1.	1100.	0.	430.	1.	1.	1.	0	0.	0.
MASK&HOSE	5.	1100.	0.	430.	3.	3.	3.	0	0.	0.
TEMP XDUCER	1.	1170.	0.	360.	0.	0.	0.	0	0.	0.
PRESS XDUCER	8.	1170.	0.	360.	0.	0.	0.	0	0.	0.

O2 SUPPLY

W= 33.0	X=	1157.27	Y=	.00	Z=	372.73
RAD OF GYRATION	KROL=	27.07	KPIT=	38.23	KYAW=	27.06
MOM OF INERTIA	ROLL=	5.	PITCH=	10.	YAW=	5.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	-5.

PLUMBING	6.	1185.	0.	360.	5.	2.	2.	0	0.	0.
CURCUITRY	5.	1185.	0.	400.	5.	2.	2.	0	0.	0.
MOUNT STRUC	9.	1185.	0.	370.	6.	3.	3.	0	0.	0.

GAS SUP SYS

W= 20.0	X=	1185.00	Y=	.00	Z=	374.50
RAD OF GYRATION	KROL=	16.27	KPIT=	15.52	KYAW=	2.50
MOM OF INERTIA	ROLL=	1.	PITCH=	1.	YAW=	0.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES (INCHES)
INTERCOOLER	14.	1210.	0.	360.	5.	8.	8.	0	0.	0.
TURBINE/COMP	11.	1210.	0.	360.	4.	4.	4.	0	0.	0.
TEMP CON VAL	8.	1210.	0.	360.	1.	1.	1.	0	0.	0.
TEMP XDUCER	4.	1210.	0.	360.	0.	0.	0.	0	0.	0.
CONTROLLER	5.	1210.	0.	400.	5.	5.	5.	0	0.	0.
CK VAL	4.	1210.	0.	370.	1.	1.	1.	0	0.	0.
REG/SHUT-OFF	12.	1210.	0.	355.	2.	2.	2.	0	0.	0.
WATER SEP	7.	1210.	0.	365.	1.	1.	1.	0	0.	0.
DISC/CK VAL	1.	1210.	0.	350.	1.	1.	1.	0	0.	0.
JP-4 PRECOOL	4.	1210.	0.	360.	4.	6.	6.	0	0.	0.
TEMP CON VAL	3.	1210.	0.	360.	1.	1.	1.	0	0.	0.
TEMP XDUCER	1.	1210.	0.	360.	0.	0.	0.	0	0.	0.
PRESS XDUCER	1.	1210.	0.	360.	0.	0.	0.	0	0.	0.
OVERHD DIFU	2.	1115.	0.	450.	2.	2.	2.	0	0.	0.
TOGGLE VAL	1.	1115.	0.	450.	1.	1.	1.	0	0.	0.
LOUVRD OUTLT	1.	1115.	0.	420.	1.	1.	1.	0	0.	0.
TEMP XDUCER	1.	1210.	0.	360.	0.	0.	0.	0	0.	0.
PRESS XDUCER	8.	1210.	0.	360.	0.	0.	0.	0	0.	0.
RAIN REM NOZ	9.	1085.	0.	435.	20.	5.	35.	0	0.	0.
REGULATOR	3.	1210.	0.	360.	1.	1.	1.	0	0.	0.
SHUT-OFF VAL	5.	1210.	0.	360.	1.	1.	1.	0	0.	0.
TEMP XDUCER	1.	1210.	0.	360.	0.	0.	0.	0	0.	0.

ITEM	WEIGHT	CENTER OF GRAVITY			RADII OF GYRATION			DIST. DATA		
	(LB)	X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
		(INCHES)			(INCHES)				(INCHES)	

AIR CYCLE

W= 106.0	X= 1195.80	Y= .00	Z= 371.42
RAD OF GYRATION	KROL= 27.14	KPIT= 46.65	KYAW= 39.79
MOM OF INERTIA	ROLL= 17.	PITCH= 50.	YAW= 36.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= -21.

*

EMERG SHUTOF	6.	1120.	0.	400.	2.	2.	2.	0	0.	0.
PRESS REG	8.	1120.	0.	400.	2.	2.	2.	0	0.	0.
SAFETY VAL	8.	1120.	0.	400.	2.	2.	2.	0	0.	0.

PRES CON MOD

W= 22.0	X= 1120.00	Y= .00	Z= 400.00
RAD OF GYRATION	KROL= 2.00	KPIT= 2.00	KYAW= 2.00
MOM OF INERTIA	ROLL= 0.	PITCH= 0.	YAW= 0.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 0.

DUCTING	126.	1210.	0.	400.	30.	1.	30.	0	0.	0.
CIRCUITRY	12.	1210.	0.	400.	10.	0.	10.	0	0.	0.
MOUNT STRUC	10.	1210.	0.	380.	8.	4.	8.	0	0.	0.
PKGING ALLOW	32.	1210.	0.	380.	10.	6.	10.	0	0.	0.

AIR CYCL SYS

W= 180.0	X= 1210.00	Y= .00	Z= 395.33
RAD OF GYRATION	KROL= 27.01	KPIT= 8.92	KYAW= 25.65
MOM OF INERTIA	ROLL= 28.	PITCH= 3.	YAW= 26.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES
PUMP PKG	82.	2023.	0.	240.	8.	8.	8.	0	0.	0.
FILTER ASSY	8.	2023.	0.	240.	2.	2.	2.	0	0.	0.
SERV CONEC	1.	2023.	0.	240.	0.	0.	0.	0	0.	0.
GH2 HT EX	29.	2023.	0.	240.	6.	6.	6.	0	0.	0.
JP-4 HT EX	6.	2023.	0.	240.	2.	6.	6.	0	0.	0.
REGEN HT EX	6.	2023.	0.	240.	2.	6.	6.	0	0.	0.
*										
TEMP CON VAL	3.	2023.	0.	240.	0.	0.	0.	0	0.	0.
TEMP CONTROL	4.	2023.	0.	240.	2.	2.	2.	0	0.	0.
GROUND HT EX	4.	2023.	0.	230.	3.	3.	3.	0	0.	0.
TEMP CON VAL	3.	2023.	0.	240.	0.	0.	0.	0	0.	0.
TEMP XDUCER	1.	2023.	0.	240.	0.	0.	0.	0	0.	0.
DISCONNECT	1.	2023.	0.	230.	0.	0.	0.	0	0.	0.
COLD PL FWD	45.	1130.	0.	400.	10.	6.	12.	0	0.	0.
COLD PL MID	27.	2023.	0.	500.	10.	6.	12.	0	0.	0.
COLD PL AFT	36.	3710.	0.	400.	10.	6.	12.	0	0.	0.
TEMP XDUCER	4.	2023.	0.	240.	0.	0.	0.	0	0.	0.
INSUL-PLUMB	43.	2500.	0.	600.	1.	750.	750.	0	0.	0.
PLUMBING	87.	2500.	0.	600.	1.	750.	750.	0	0.	0.
CIRCUITRY	15.	2023.	0.	240.	5.	5.	5.	0	0.	0.
MOUNT STRUC	15.	2023.	0.	240.	10.	10.	10.	0	0.	0.
PKGING ALLOW	35.	2023.	0.	240.	12.	12.	12.	0	0.	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES

HT TRANS SYS

W= 455.0	X= 2204.44	Y= .00	Z= 386.66
RAD OF GYRATION	KROL= 155.38	KPIT= 721.78	KYAW= 704.91
MOM OF INERTIA	ROLL= 2371.	PITCH= 51163.	YAW= 48800.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 2915.

CABIN INSUL	172.	1120.	0.	430.	25.	30.	30.	0	0.	0.
GROUND PURGE	348.	3000.	0.	600.	10.	700.	700.	0	0.	0.
HE FLGT PRGE	362.	3715.	0.	400.	20.	20.	20.	0	0.	0.
ENG BLED AIR	106.	2800.	0.	500.	100.	750.	750.	0	0.	0.
* CONTINGENCY	187.	2400.	0.	400.	100.	600.	600.	0	0.	0.

PURGE SYS

W= 1175.0	X= 2831.55	Y= .00	Z= 472.65
RAD OF GYRATION	KROL= 101.69	KPIT= 984.08	KYAW= 980.21
MOM OF INERTIA	ROLL= 2623.	PITCH= 245603.	YAW= 243674.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 552.

SUB-TOTAL - ECLS

W= 2058.0	X= 2352.24	Y= .00	Z= 434.66
RAD OF GYRATION	KROL= 115.44	KPIT= 1041.89	KYAW= 1036.30
MOM OF INERTIA	ROLL= 5919.	PITCH= 482197.	YAW= 477035.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 14461.

CREW SEATS	120.	1125.	0.	420.	10.	10.	10.	1	1125.	0.
EMERG EQUIP	29.	1163.	0.	430.	5.	2.	5.	1	1163.	0.
FURNISHINGS	139.	1107.	0.	425.	25.	15.	20.	0	1090.	1120.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA (INCHES)		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES

PERS PROV

W=	288.0	X=	1120.14	Y=	.00	Z=	423.42
RAD OF GYRATION		KROL=	18.88	KPIT=	20.99	KYAW=	22.72
MOM OF INERTIA		ROLL=	22.	PITCH=	27.	YAW=	32.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	1.

SUB-TOTAL - PERS PROV

W=	288.0	X=	1120.14	Y=	.00	Z=	423.42
RAD OF GYRATION		KROL=	18.88	KPIT=	20.99	KYAW=	22.72
MOM OF INERTIA		ROLL=	22.	PITCH=	27.	YAW=	32.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	1.

SUB-TOTAL - BALLAST

W=	.0	X=	.00	Y=	.00	Z=	.00
RAD OF GYRATION		KROL=	.00	KPIT=	.00	KYAW=	.00
MOM OF INERTIA		ROLL=	0.	PITCH=	0.	YAW=	0.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

SUB-TOTAL - PEND CHNGS

W=	.0	X=	.00	Y=	.00	Z=	.00
RAD OF GYRATION		KROL=	.00	KPIT=	.00	KYAW=	.00
MOM OF INERTIA		ROLL=	0.	PITCH=	0.	YAW=	0.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
GROWTH UNCER	42009.	3095.	0.	420.	100.	600.	600.	0	1030.	3930.

GROWTH

W= 42009.0	X=	3095.00	Y=	.00	Z= 420.00
RAD OF GYRATION	KROL=	100.00	KPIT=	600.00	KYAW= 600.00
MOM OF INERTIA	ROLL=	90674.	PITCH=	3264233.	YAW= 3264232.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= 8.

SUB-TOTAL - GROWTH

W= 42009.0	X=	3095.00	Y=	.00	Z= 420.00
RAD OF GYRATION	KROL=	100.00	KPIT=	600.00	KYAW= 600.00
MOM OF INERTIA	ROLL=	90674.	PITCH=	3264234.	YAW= 3264232.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= 8.

ACCUM. TOTAL - DRY WT

W= 575526.0	X=	3163.50	Y=	.15	Z= 426.07
RAD OF GYRATION	KROL=	307.23	KPIT=	837.71	KYAW= 869.20
MOM OF INERTIA	ROLL=	11725441.	PITCH=	87173904.	YAW= 93850016.
PROD OF INERTIA	ROL-PIT=	-14106.	PIT-YAW=	2272.	YAW-ROL= 5388062.

PERSONNEL	522.	1110.	0.	425.	24.	14.	20.	1	1110.	0.

PERSONNEL

W= 522.0	X=	1110.00	Y=	.00	Z= 425.00
RAD OF GYRATION	KROL=	24.00	KPIT=	14.00	KYAW= 20.00
MOM OF INERTIA	ROLL=	65.	PITCH=	22.	YAW= 45.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= 0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	

SUB-TOTAL - PERSONNEL

W=	522.0	X=	1110.00	Y=	.00	Z= 425.00
RAD OF GYRATION		KROL=	24.00	KPIT=	14.00	KYAW= 20.00
MOM OF INERTIA		ROLL=	65.	PITCH=	22.	YAW= 45.
PROD OF INERTIA		ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL= 0.

GH MN TK	741.	2858.	0.	400.	0.	0.	0.	0	2163.	3553.
GO MN TK	4055.	1655.	0.	400.	0.	0.	0.	0	1235.	1883.
CRU RESI FWD	1310.	2023.	0.	400.	0.	0.	0.	1	2023.	0.
CR RES RT WG	655.	3845.	-500.	600.	0.	0.	0.	1	3845.	0.
CR RES LF WG	655.	3845.	500.	600.	0.	0.	0.	1	3845.	0.
CR RES LINES	1425.	3016.	0.	400.	0.	200.	200.	0	2023.	3625.
ACS/APU TK	76.	2023.	50.	540.	0.	0.	0.	1	2023.	0.
ACS H2 L&A	46.	2023.	0.	550.	0.	0.	0.	0	1953.	2093.
ACS O2 L&A	213.	2023.	100.	530.	0.	0.	0.	0	1953.	2093.
PNEU HE	27.	3740.	0.	400.	0.	0.	0.	1	3740.	0.
HYDR FLUID	5381.	3700.	0.	400.	200.	500.	500.	0	0.	0.
FREON	54.	2023.	0.	400.	0.	0.	0.	0	0.	0.
ECLS AIR	28.	1190.	0.	360.	0.	0.	0.	0	0.	0.
ECLS O2 *	2.	1170.	0.	360.	0.	0.	0.	0	0.	0.
JP-4/APU	39.	2023.	0.	540.	0.	0.	0.	0	0.	0.

RESIDUALS

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	

W= 14707.0 X= 2837.14 Y= 1.71 Z= 421.18
RAD OF GYRATION KROL= 201.60 KPIT= 967.27 KYAW= 976.96
MOM OF INERTIA ROLL= 129020. PITCH= 2969996. YAW= 3029792.
PROD OF INERTIA ROL-PIT= -4411. PIT-YAW= 598. YAW-ROL= 48515.

SUB-TOTAL - RESIDUALS

W= 14707.0 X= 2837.14 Y= 1.71 Z= 421.18
RAD OF GYRATION KROL= 201.60 KPIT= 967.27 KYAW= 976.96
MOM OF INERTIA ROLL= 129020. PITCH= 2969996. YAW= 3029792.
PROD OF INERTIA ROL-PIT= -4411. PIT-YAW= 598. YAW-ROL= 48515.

CR RESER LFT	5000.	3845.	-500.	600.	0.	0.	0.	1	3845.	0.
CR RESER RT	5000.	3845.	500.	600.	0.	0.	0.	1	3845.	0.
ACPS RES	54.	2023.	50.	540.	0.	0.	0.	1	2023.	0.
APU RES	17.	2023.	50.	540.	0.	0.	0.	1	2023.	0.
JP-4/APU	174.	2023.	0.	540.	0.	0.	0.	0	0.	0.

RESERVE

W= 10245.0 X= 3801.43 Y= .35 Z= 598.56
RAD OF GYRATION KROL= 494.09 KPIT= 278.54 KYAW= 567.04
MOM OF INERTIA ROLL= 539825. PITCH= 171557. YAW= 711009.
PROD OF INERTIA ROL-PIT= -1363. PIT-YAW= -45. YAW-ROL= 5647.

SUB-TOTAL - RESERVE

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA (INCHES)		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES

W= 10245.0 X= 3801.43 Y= .35 Z= 598.56
RAD OF GYRATION KROL= 494.09 KPIT= 278.54 KYAW= 567.04
MOM OF INERTIA ROLL= 539825. PITCH= 171557. YAW= 711009.
PROD OF INERTIA ROL-PIT= -1363. PIT-YAW= -45. YAW-ROL= 5647.

ACCUM. TOTAL - LANDING WT

W= 601000.0 X= 3164.61 Y= .19 Z= 428.89
RAD OF GYRATION KROL= 309.91 KPIT= 842.58 KYAW= 874.94
MOM OF INERTIA ROLL= 12459170. PITCH= 92093504. YAW= 99304064.
PROD OF INERTIA ROL-PIT= -21186. PIT-YAW= 2861. YAW-ROL= 5690488.

DUMP PROP 34000. 3845. 0. 600. 0. 0. 0. 1 3845. 0.
*

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	

CRU RESR DMP

W= 34000.0	X=	3845.00	Y=	.00	Z=	600.00
RAD OF GYRATION	KROL=	.00	KPIT=	.00	KYAW=	.00
MOM OF INERTIA	ROLL=	0.	PITCH=	0.	YAW=	0.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

SUB-TOTAL - CRU RESR DMP

W= 34000.0	X=	3845.00	Y=	.00	Z=	600.00
RAD OF GYRATION	KROL=	.00	KPIT=	.00	KYAW=	.00
MOM OF INERTIA	ROLL=	0.	PITCH=	0.	YAW=	0.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

ACCUM. TOTAL - END OF CRUSE

W= 635000.0	X=	3201.04	Y=	.18	Z=	438.05
RAD OF GYRATION	KROL=	303.95	KPIT=	834.79	KYAW=	864.87
MOM OF INERTIA	ROLL=	12662566.	PITCH=	95512080.	YAW=	102519232.
PROD OF INERTIA	ROL-PIT=	-22082.	PIT-YAW=	2636.	YAW-ROL=	6499232.

CRU PROP FWD	75814.	2023.	0.	370.	0.	0.	0.	1	2023.	0.
CR PR LFT WG	5593.	3845.	-500.	600.	0.	0.	0.	1	3845.	0.
CR PR RT WG	5593.	3845.	500.	600.	0.	0.	0.	1	3845.	0.

CRU PRO USED

W= 87000.0	X=	2257.26	Y=	.00	Z=	399.57
RAD OF GYRATION	KROL=	195.12	KPIT=	614.72	KYAW=	635.68
MOM OF INERTIA	ROLL=	714901.	PITCH=	7095806.	YAW=	7588099.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	881691.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	

SUB-TOTAL - CRU PRO USED

W= 87000.0	X=	2257.26	Y=	.00	Z=	399.57
RAD OF GYRATION	KROL=	195.12	KPIT=	614.72	KYAW=	635.68
MOM OF INERTIA	ROLL=	714901.	PITCH=	7095804.	YAW=	7588097.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	881691.

APU-02	126.	2023.	100.	540.	0.	0.	0.	1	2023.	0.
APU-H2	168.	2023.	0.	540.	0.	0.	0.	1	2023.	0.
JP-4/APU	1741.	2023.	0.	540.	0.	0.	0.	0	0.	0.

APU PROP

W= 2035.0	X=	2023.00	Y=	6.19	Z=	540.00
RAD OF GYRATION	KROL=	24.10	KPIT=	1.46	KYAW=	24.06
MOM OF INERTIA	ROLL=	255.	PITCH=	-1.	YAW=	254.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

SUB-TOTAL - APU PROP

W= 2035.0	X=	2023.00	Y=	6.19	Z=	540.00
RAD OF GYRATION	KROL=	24.10	KPIT=	1.46	KYAW=	24.06
MOM OF INERTIA	ROLL=	255.	PITCH=	-1.	YAW=	254.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

ACCUM. TOTAL - CRUISE START

W= 724035.0	X=	3084.32	Y=	.17	Z=	433.71
RAD OF GYRATION	KROL=	292.90	KPIT=	868.38	KYAW=	895.48
MOM OF INERTIA	ROLL=	13407175.	PITCH=	117843984.	YAW=	125314272.
PROD OF INERTIA	ROL-PIT=	-22097.	PIT-YAW=	3031.	YAW-ROL=	7931077.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
H2 PRESS	526.	2858.	0.	400.	0.	0.	0.	0	2163.	3553.
O2 PRESS	366.	1655.	0.	400.	0.	0.	0.	0	1235.	1883.
LH2 TK RES	1000.	3659.	0.	400.	0.	0.	.	1	3553.	0.
LO2 TK RES	1700.	1993.	0.	400.	0.	0.	0.	1	1883.	0.
LH2 LN RES	115.	3720.	0.	400.	0.	0.	0.	0	3670.	3792.
LO2 LN RES	1900.	2887.	0.	400.	0.	0.	0.	0	1983.	3792.
LH2 ENG RS	480.	3792.	0.	400.	0.	0.	0.	1	3792.	0.
LO2 ENG RS	8160.	3792.	0.	400.	0.	0.	0.	1	3792.	0.
PU BIAS	4841.	3625.	0.	400.	0.	0.	0.	1	3553.	0.
ACPS SERV	278.	2023.	50.	540.	0.	0.	0.	1	2023.	0.
PNEU HE	68.	3740.	0.	400.	0.	0.	0.	1	3740.	0.
JP-4/PURGE	137.	2023.	0.	400.	0.	0.	0.	0	0.	0.
CHIL DOWN H2	15.	2858.	0.	400.	0.	0.	0.	0	0.	0.
CHIL DOWN O2	365.	1655.	0.	400.	0.	0.	0.	0	0.	0.
SHUT-DOWN H2	324.	2858.	0.	400.	0.	0.	0.	0	0.	0.
SHUT-DOWN O2	528.	1655.	0.	400.	0.	0.	0.	0	0.	0.
ACPS COOL H2	5.	2858.	0.	400.	0.	0.	0.	0	0.	0.
ACPS COOL O2	4.	1655.	0.	400.	0.	0.	0.	0	0.	0.

INFLT LOSS

W=	20812.0	X=	3312.62	Y=	.67	Z= 401.87
RAD OF GYRATION		KROL=	17.07	KPIT=	702.12	KYAW= 701.96
MOM OF INERTIA		ROLL=	1309.	PITCH=	2214476.	YAW= 2213463.
PROD OF INERTIA		ROL-PIT=	-3869.	PIT-YAW=	414.	YAW-ROL= -10829.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	

SUB-TOTAL - INFLT LOSS

W= 20812.0	X= 3312.62	Y= .67	Z= 401.87
RAD OF GYRATION	KROL= 17.07	KPIT= 702.12	KYAW= 701.96
MOM OF INERTIA	ROLL= 1309.	PITCH= 2214477.	YAW= 2213463.
PROD OF INERTIA	ROL-PIT= -3869.	PIT-YAW= 414.	YAW-ROL= -10829.

ORIENT O2	991.	2023.	100.	400.	0.	0.	0.	1	2023.	0.
ORIENT H2	221.	2023.	0.	400.	0.	0.	0.	1	2023.	0.

ORIENT PROP

W= 1212.0	X= 2023.00	Y= 81.77	Z= 400.00
RAD OF GYRATION	KROL= 38.61	KPIT= .00	KYAW= 38.61
MOM OF INERTIA	ROLL= 390.	PITCH= 0.	YAW= 390.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 0.

SUB-TOTAL - ORIENT PROP

W= 1212.0	X= 2023.00	Y= 81.77	Z= 400.00
RAD OF GYRATION	KROL= 38.61	KPIT= .00	KYAW= 38.61
MOM OF INERTIA	ROLL= 390.	PITCH= 0.	YAW= 390.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 0.

SUB-TOTAL - PEND CHNGS

W= .0	X= .00	Y= .00	Z= .00
RAD OF GYRATION	KROL= .00	KPIT= .00	KYAW= .00
MOM OF INERTIA	ROLL= 0.	PITCH= 0.	YAW= 0.
PROD OF INERTIA	ROL-PIT= 0.	PIT-YAW= 0.	YAW-ROL= 0.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	

ACCUM. TOTAL - BURN OUT WT

W= 746059.0 X= 3088.97 Y= .32 Z= 432.77
RAD OF GYRATION KROL= 288.63 KPIT= 865.37 KYAW= 891.76
MOM OF INERTIA ROLL= 13415379. PITCH=120588672. YAW= 128055312.
PROD OF INERTIA ROL-PIT= -48223. PIT-YAW= 2678. YAW-ROL= 7897963.

LOX(25%)	651129.	1888.	0.	400.	0.	68.	68.	0	0.	0.
LH2(25%)	108521.	3450.	0.	400.	0.	84.	84.	0	0.	0.

ASCENT PROP

W= 759650.0 X= 2111.14 Y= .00 Z= 400.00
RAD OF GYRATION KROL= .42 KPIT= 551.12 KYAW= 551.11
MOM OF INERTIA ROLL= 28. PITCH= 49800240. YAW= 49800208.
PROD OF INERTIA ROL-PIT= 0. PIT-YAW= 0. YAW-ROL= 99.

SUB-TOTAL - ASCENT PROP

W= 759650.0 X= 2111.14 Y= .00 Z= 400.00
RAD OF GYRATION KROL= .42 KPIT= 551.12 KYAW= 551.11
MOM OF INERTIA ROLL= 28. PITCH= 49800256. YAW= 49800224.
PROD OF INERTIA ROL-PIT= 0. PIT-YAW= 0. YAW-ROL= 99.

ACCUM. TOTAL - 75% BURN

W= 1505709.0 X= 2595.64 Y= .16 Z= 416.24
RAD OF GYRATION KROL= 203.83 KPIT= 873.82 KYAW= 886.72
MOM OF INERTIA ROLL= 13502613. PITCH=248154016. YAW= 255533568.
PROD OF INERTIA ROL-PIT= -22714. PIT-YAW= 3533. YAW-ROL= 10501252.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES (INCHES)
LOX(25%)	-651129.	1888.	0.	400.	0.	68.	68.	0	0.	0.
LH2(25%)	-108521.	3450.	0.	400.	0.	84.	84.	0	0.	0.
LOX(50%)	1302257.	1816.	0.	400.	0.	87.	87.	0	0.	0.
LH2(50%)	217043.	3275.	0.	400.	0.	158.	158.	0	0.	0.

ASCENT PROP

W= 759650.0	X=	1937.72	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	.66	KPIT=	471.86	KYAW=	471.86
MOM OF INERTIA	ROLL=	71.	PITCH=	36507376.	YAW=	36507296.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	198.

SUB-TOTAL - ASCENT PROP

W= 759650.0	X=	1937.72	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	.66	KPIT=	471.86	KYAW=	471.86
MOM OF INERTIA	ROLL=	71.	PITCH=	36507376.	YAW=	36507312.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	198.

ACCUM. TOTAL - 50% BURN

W= 2265359.0	X=	2375.02	Y=	.11	Z=	410.79
RAD OF GYRATION	KROL=	166.36	KPIT=	823.85	KYAW=	832.92
MOM OF INERTIA	ROLL=	13531427.	PITCH=	331865344.	YAW=	339215872.
PROD OF INERTIA	ROL-PIT=	-11305.	PIT-YAW=	3814.	YAW-ROL=	11665920.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS (INCHES)	ES (INCHES)
LOX(50%)	-651128.	1816.	0.	400.	0.	87.	87.	0	0.	0.
LOX(50%)	-651129.	1816.	0.	400.	0.	87.	87.	0	0.	0.
LH2(50%)	-217043.	3275.	0.	400.	0.	158.	158.	0	0.	0.
LOX(75%)	1953386.	1744.	0.	400.	0.	92.	92.	0	0.	0.
LH2(75%)	325564.	3100.	0.	400.	0.	268.	268.	0	0.	0.

ASCENT PROP

W= 759650.0	X=	1764.28	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	.42	KPIT=	376.12	KYAW=	376.12
MOM OF INERTIA	ROLL=	28.	PITCH=	23195184.	YAW=	23195168.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	99.

SUB-TOTAL - ASCENT PROP

W= 759650.0	X=	1764.28	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	.42	KPIT=	376.12	KYAW=	376.12
MOM OF INERTIA	ROLL=	28.	PITCH=	23195184.	YAW=	23195168.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	99.

ACCUM. TOTAL - 25% BURN

W= 3025009.0	X=	2221.65	Y=	.08	Z=	408.08
RAD OF GYRATION	KROL=	144.04	KPIT=	783.57	KYAW=	790.70
MOM OF INERTIA	ROLL=	13545799.	PITCH=	400877568.	YAW=	408214016.
PROD OF INERTIA	ROL-PIT=	-3375.	PIT-YAW=	3955.	YAW-ROL=	12475485.

ITEM	WEIGHT (LB)	CENTER OF GRAVITY (INCHES)			RADII OF GYRATION (INCHES)			DIST. DATA		
		X	Y	Z	ROLL	PITCH	YAW	DI	BS	ES
									(INCHES)	
LOX(75%)	-976693.	1744.	0.	400.	0.	92.	92.	0	0.	0.
LOX(75%)	-976693.	1744.	0.	400.	0.	92.	92.	0	0.	0.
LH2(75%)	-325564.	3100.	0.	400.	0.	268.	268.	0	0.	0.
LOX(100%)	2604514.	1676.	0.	400.	0.	146.	146.	0	0.	0.
LH2(100%)	434086.	2925.	0.	400.	0.	376.	376.	0	0.	0.

ASCENT PROP

W= 759650.0	X=	1604.57	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	.29	KPIT=	326.66	KYAW=	326.66
MOM OF INERTIA	ROLL=	-14.	PITCH=	17496176.	YAW=	17496192.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

SUB-TOTAL - ASCENT PROP

W= 759650.0	X=	1604.57	Y=	.00	Z=	400.00
RAD OF GYRATION	KROL=	.29	KPIT=	326.66	KYAW=	326.66
MOM OF INERTIA	ROLL=	-14.	PITCH=	17496176.	YAW=	17496192.
PROD OF INERTIA	ROL-PIT=	0.	PIT-YAW=	0.	YAW-ROL=	0.

ACCUM. TOTAL - LAUNCH WT

W= 3784659.0	X=	2097.79	Y=	.06	Z=	406.46
RAD OF GYRATION	KROL=	128.81	KPIT=	757.14	KYAW=	763.04
MOM OF INERTIA	ROLL=	13554385.	PITCH=	468285184.	YAW=	475612928.
PROD OF INERTIA	ROL-PIT=	3030.	PIT-YAW=	4038.	YAW-ROL=	13129111.